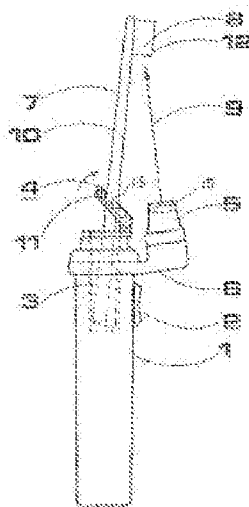


TOOTHBRUSH DEVICE OF MOUTH LIGHTENING TYPE**Publication number:** JP2174804 (A)**Publication date:** 1990-07-06**Inventor(s):** FUKUBA HIROSHI**Applicant(s):** FUKUBA HIROSHI**Classification:**- **international:** **A46B15/00; A61C17/00; A46B15/00; A61C17/00;** (IPC1-7): A46B15/00; A61C17/00- **European:****Application number:** JP19880330599 19881227**Priority number(s):** JP19880330599 19881227**Abstract of JP 2174804 (A)**

PURPOSE:To prevent plaque from being left so as to be able to easily confirm a place with which the top ends of brushing hairs comes into contact by providing both a main body which can hold a toothbrush and a lightening device by which light can be applied near the place where the hairs are planted on the toothbrush. **CONSTITUTION:**After a toothbrush 7 is held in a main body 1 and this main body is held by the hand, a switching knob 2 is operated. The toothbrush 7 thus starts a shuttle motion and the light of a lightening device 5 is applied to a place 8 where hairs are planted. For that reason, since a place with which top ends 12 of the brushing hairs comes into contact on the surface of teeth is brightly lightened by only touching the top ends 12 of the brushing hairs of the toothbrush 7 on the teeth and can be precisely confirmed by the eyes through a mirror or the like, the top ends 12 of the brushing hairs can be fully reached to all parts of the teeth. At the same time, since a place 3 where the toothbrush is placed is shuttled, brushing with the toothbrush 7 is done without moving the hand and plaque is removed. Furthermore, a shuttle motion, e.g. the amplitude of vibration in its axial direction is about 4mm and the number thereof is about 2300 per minute, is suitable for the vibration of the toothbrush 7.



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⑫ 公開特許公報(A)

平2-174804

⑤ Int. Cl.⁵A 46 B 15/00
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識別記号

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⑬ 公開 平成2年(1990)7月6日

7108-4C A 61 C 17/00

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審査請求 未請求 請求項の数 1 (全3頁)

⑭ 発明の名称 口腔照明式歯ブラシ装置

⑮ 特 願 昭63-330599

⑯ 出 願 昭63(1988)12月27日

⑰ 発 明 者 福 場 博 千葉県流山市名都借914-1

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⑲ 代 理 人 弁理士 稲 葉 良 幸

明 細 書

1. 発明の名称

口腔照明式歯ブラシ装置

2. 特許請求の範囲

(1) 歯ブラシを保持し得る本体と、本体に設置され、該本体に保持される歯ブラシの植毛部付近に光を照射する照明装置と、を備えた口腔照明式歯ブラシ装置。

3. 発明の詳細な説明

〔産業上の利用分野〕

本発明は口腔照明式の歯ブラシ装置に関する。

〔従来の技術〕

歯ブラシを使用して歯を磨くことの目的は歯に付着しているプラーク(歯垢)を取り除くことである。プラークが歯面に付着したまま放置すると虫歯に、プラークが歯と歯の境目に付着したまま放置すると歯槽ノローになることはよく知られている。殆どの人がこれらの歯の病気に悩んでいるというデータが厚生省などで発表されている。この事実プラークを除去するという歯ブラ

シ使用の目的が充分達成されていないことを示している。

プラークは歯ブラシの毛先がその部分に届くようにブラッシングされれば除去できることもよく知られている。多数の人が毎日ブラッシングしているにもかかわらず、プラークが充分に除去できないということは、すなわち、実際にはブラシ毛先が歯の隅々に届いていないのである。

〔発明が解決しようとする課題〕

ブラシ毛先が歯の隅々に届かない最大の理由は、特に口腔内の歯の裏側や奥歯付近が暗くて鏡を通して目で確認することができず、その部分のブラッシングは視覚に頼らずに触覚などの曖昧な感覚に委ねられているからである。そこで、懐中電灯などを利用して口腔内を明るく照らすことも考えられるが、片手に電灯を持ち、他方の手でブラッシングするという煩雑さは日常のブラッシングには馴染まない。

本発明は、このような問題点を解消すべくなされたもので、その目的とするところは、ブラッシ

ングをする際に自動的にブラシ毛先とそれが接触する歯の部分をもるく照らすことができるようにすることにより、通常目で確認し難い部分まで鏡などを介して容易にこれら部分を確認でき、もってブラシ毛先を歯の隅々まで届かせることによりブラークの取り残しを極力防止した口腔照明式歯ブラシ装置を提供するにある。

〔課題を解決するための手段〕

本発明は、このような目的を達成するために、歯ブラシを保持し得る本体と、本体に設置され、該本体に保持される歯ブラシの植毛部付近に光を照射する照明装置と、を備えたものである。

〔作用〕

このように、装置の本体に歯ブラシを保持し、本体を手にとって歯ブラシでブラッシングするだけで、ブラシ毛先が当接する部分が照明装置で明るく照らされることになり、この部分を鏡などを介して容易に確認することができる。

〔実施例〕

以下本発明を図面に示す実施例に基いて説明す

ラシ7の柄10をその基端部から保持部材4のリングの中を通して歯ブラシ受領部3に挿入し、その後歯ブラシ保持部材4を解放すればよい。これにより、ばね13の付勢力によって前記保持部材4の当接部11が歯ブラシの柄10を半径方向外側に押圧し、歯ブラシ7を容易に抜けないように保持する。なお前記保持部材4の当接部11は、例えばゴムなどの弾性体で形成される方が歯ブラシの抜け止め効果には好適である。

符号5は電球15を有する照明装置であり、アーム6を介して本体1、特にその上部付近に取付けられている。電球15は前記スイッチノブ2に電気的に接続され、スイッチノブ2の操作による歯ブラシ受領部3の往復動と同時に点灯するようになっている。この電球15は、矢印9で示すように歯ブラシ受領部3に挿入されて保持された歯ブラシ7のブラシ植毛部8付近に光を照射するように方向づけられている。

このような構成の装置は口腔照明式の電動歯ブラシ装置として機能し、従って、歯ブラシ7を本

る。なお、この実施例は、本発明を電動歯ブラシ装置に応用したものである。すなわち、図において、符号1は筒状の本体であり、歯ブラシ受領部3をその略軸線方向に移動可能に備えている。本体1内にはいわゆる電動歯ブラシ装置に使用される公知のモータおよび駆動装置(図示省略)が収納され、スイッチノブ2を操作することによりモータが回転駆動し、この回転駆動が駆動装置により略軸線方向の往復動に変換されて歯ブラシ受領部3に伝達され、これにより歯ブラシ受領部3は往復動する。この構造は例えば特開昭58-105709号公報に記載され公知であるので詳しい説明は省略する。

歯ブラシ受領部3には歯ブラシ保持部材4が挿動可能に取付けられ、この実施例では略リング状に形成されるとともに、弾発部材、例えばばね13により図における時計方向に付勢されている。歯ブラシ7をこの歯ブラシ受領部3に挿入して保持する際には、まず前記保持部材4をばねの付勢力に抗して図の反時計方向に回動させ、歯ブ

体1に保持してこの本体を手で把持してスイッチノブ2を操作することにより、歯ブラシ7は往復運動を開始し、同時に照明装置5により植毛部8が光で照射される。よって、歯ブラシ7のブラシ毛先12を歯に当てるだけで、歯面とブラシ毛先12との接触部が明るく照らされ、鏡などを介して詳細に目で確認することができ、ブラシ毛先12を歯の隅々にまで十分に届かせることができる。これとともに、歯ブラシ受領部3が往復動するので、手を動かさなくても歯ブラシ7によるブラッシング行なわれ、ブラークが除去されることになる。なお歯ブラシ7の振動としてはその軸線方向に約4mmの振幅で1分間約2300回の往復運動をするのが好適である。

なお上記実施例に変え、照明装置5専用のスイッチを前述の電動用のスイッチノブ2とは別個に本体に設けるようにしてもよい。また、照明装置5のアーム6の取付け角度等を可変とし、光の照射方向を調節できるようにしてもよい。

さらに、本発明は、電動歯ブラシ装置にこれを

適用することには限定する必要はなく、例えば前述のモータや駆動装置がなく、電動方式を採らない本体に照明装置を取付けたものでもよく、さらには照明装置を歯ブラシの柄に取付けるようにしてもよい。

〔効果〕

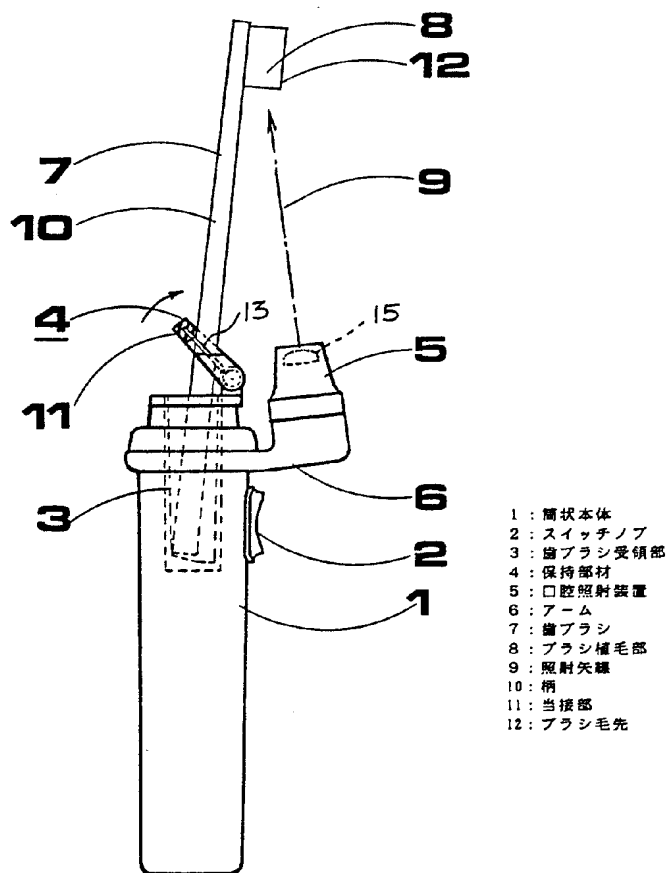
以上のように本発明によれば、ブラシの毛先とそれが接触する歯の部分とを明るく照らしながらブラッシングすることが可能となり、詳細な部分まで目で確認できて毛先を歯の隅々に届かすことが容易となり、ブランクの取り残しという問題を解決して歯の健康維持に大きく寄与することができるという優れた効果がある。

4. 図面の簡単な説明

図は本発明に係る口腔照明式歯ブラシ装置の一実施例を示す正面図である。

- 1 … 本体、 4 … 歯ブラシ保持部材
5 … 照明装置、 7 … 歯ブラシ
8 … ブラシ植毛部

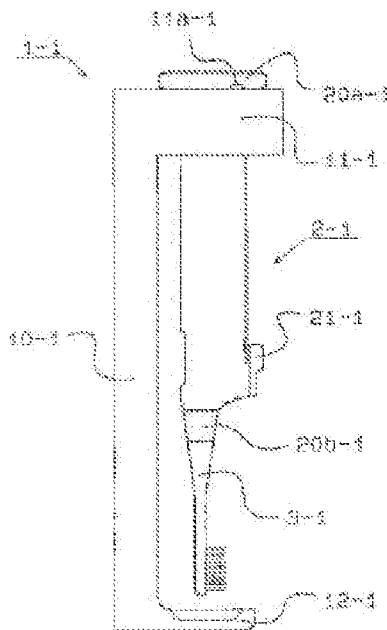
代理人 弁理士 稲 葉 良 幸



ELECTRIC TOOTHBRUSH SET**Publication number:** JP10014661 (A)**Publication date:** 1998-01-20**Inventor(s):** MOGAMI KINUE**Applicant(s):** MOGAMI KINUE**Classification:**- **international:** **A46B13/02; A46B15/00; A61C17/22; A46B13/00; A46B15/00; A61C17/16;** (IPC-7): A46B13/02; A46B15/00; A61C17/22- **European:****Application number:** JP19960179273 19960709**Priority number(s):** JP19960179273 19960709**Abstract of JP 10014661 (A)**

PROBLEM TO BE SOLVED: To prevent a toothbrush itself from becoming dirty by waterdrops adhering near a toothbrush member during charging by holding the toothbrush body so that its handle may be located higher than the toothbrush member with a toothbrush body holder.

SOLUTION: A toothbrush body holder 1-1 wherein a holding part 11 is protruded from the upper edge orthogonally of an oblong rectangular flat part 10-1, and a waterdrop pan 12-1 is protruded orthogonally from the lower edge of the flat part 10-1 in the same direction as the holding part 11-1, is fitted to the surface of a wall. Then the toothbrush body holder 1-1 is held so that a toothbrush body 2-1 may be higher than a toothbrush member 3-1. Therefore, during charging, the part between the toothbrush body 2-1 and the toothbrush member 301 and irregularities of the toothbrush body 2-1 and the like are protected from becoming dirty by waterdrops adhering near the toothbrush member 3-1, and sanitairiness is ensured.

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(19)日本国特許庁 (J P)

(12) 公 開 特 許 公 報 (A)

(11)特許出願公開番号

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A 6 1 C	17/22		15/00	K
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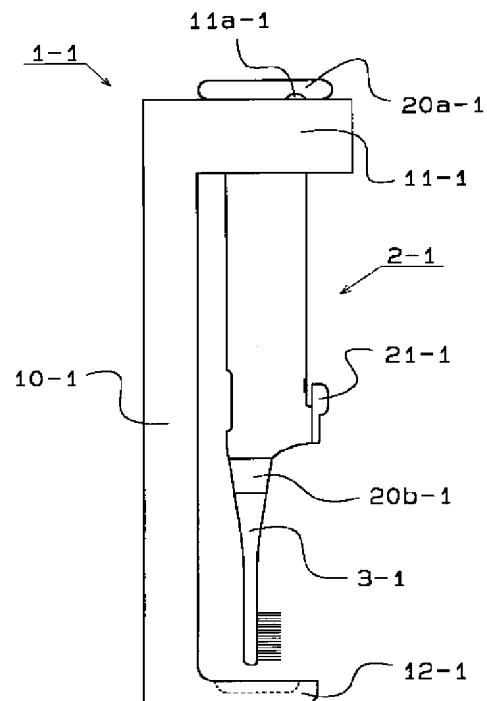
(74)代理人 弁理士 最上 正太郎

(54)【発明の名称】 電動式歯ブラシセット

(57)【要約】

【課題】歯ブラシ部材付近に付着している水滴によって、歯ブラシ本体等が汚されることがないようにする。

【解決手段】電動式歯ブラシにおいて、歯ブラシ本体保持具1-1が、歯ブラシ本体2-1を、その柄部が歯ブラシ部材3-1よりも高い位置になるよう保持するようにし、歯ブラシ部材3-1に付着した水滴が歯ブラシ本体2-1の方へ流れて行かないようにする。



【特許請求の範囲】

【請求項1】 歯ブラシ本体保持具(1-1、1-2)

と、

歯ブラシ部材(3-1、3-2)と、

一端部は柄部として構成され、他の一端に上記歯ブラシ部材(3-1、3-2)を着脱自在に取り付け得るブラシ取付部(20b-1、20b-2)を有する筐体(20-1、20-2)の内部に、電池と、その電池の出力電流により駆動される電動機と、その電動機の運動を所望の運動に変換し、ブラシ取付部(20b-1、20b-2)に伝達する変換機構とを収容し、さらに、上記電動機の電源回路の電流をオンオフし得るスイッチ(21-1)を設けて成る歯ブラシ本体(2-1、2-2)

と、

により構成される、電動式歯ブラシセットにおいて、歯ブラシ本体保持具(1-1、1-2)が、歯ブラシ本体(2-1、2-2)を、その柄部が歯ブラシ部材(3-1、3-2)よりも高い位置になるよう保持することを特徴とする、上記の電動式歯ブラシセット。

【発明の詳細な説明】**【0001】**

【発明の属する技術分野】 本発明は、電動式歯ブラシセットに関する。

【0002】

【従来の技術】 電動式歯ブラシは、歯ブラシ本体に歯ブラシ部材を取り付け、歯ブラシ本体に内蔵された電動機の運動を所要の運動に変換して歯ブラシ部材に伝え、歯ブラシ部材をブラッシング運動させるものである。このような電動式歯ブラシは、歯磨きをする人の力やブラッシングテクニックに拘わらず、確実に食べカスや歯垢を除去できるため、子供から老人まで幅広く利用されている。しかし、従来の電動式歯ブラシセットにおいては、使用後の歯ブラシ本体を、歯ブラシ部材を上にしてスタンドに立てるものであるため、歯ブラシ部材のブラシ付近に付着している水滴が歯ブラシ本体や歯ブラシ部材の表面を伝って流れ落ちてしまう。

【0003】 この水滴は、歯ブラシ部材の取付部やスイッチ周辺の隙間や凹部に入り込んだり、また、スタンドの歯ブラシ本体受け部分に溜まるが、この水滴には、歯ブラシ部材や歯ブラシ本体の表面に付着している汚れや、流れ落ちる途中で接した空中の塵などが含まれているため、水滴が溜まりやすい部分にはすぐに汚れが堆積し、不衛生で見栄えも悪くなるという問題があった。このため、従来の電動式歯ブラシセットにおいては、歯ブラシ本体やスタンド等を頻繁に洗浄しなければならず、非常に面倒臭い上、この汚れは隙間などの非常に洗浄し難い部分に堆積するので、その洗浄作業は極めて困難で、家庭でできるような簡単な洗浄方法では汚れを完全に除去することはできなかった。

【0004】

【発明が解決しようとする課題】 本発明は上記の問題を解決するためになされたものであり、その目的とするところは、充電中に歯ブラシ部材付近に付着している水滴によって、歯ブラシ本体等が汚されることがない電動式歯ブラシセットを提供することにある。

【0005】

【課題を解決するための手段】 上記の目的は、電動式歯ブラシセットにおいて、歯ブラシ本体保持具が、歯ブラシ本体を、その柄部が歯ブラシ部材よりも高い位置になるよう保持するようにし、歯ブラシ部材に付着した水滴が歯ブラシ本体の方へ流れて行かないようにすることによって達成される。

【0006】

【発明の実施の態様】 以下、図面を参照しつつ本発明の詳細を説明する。図1は本発明に係る電動式歯ブラシセットの第一実施例を示す正面図、図2は図1に示した電動式歯ブラシセットの側面図、図3は図1に示した歯ブラシ本体保持具の上面図、図4は本発明に係る電動式歯ブラシセットの第二実施例を示す正面図、図5は図4に示した電動式歯ブラシセットの側面図である。

【0007】 まず、図1ないし図3に基づき、第一実施例について説明する。図中、1-1は歯ブラシ本体保持具、2-1は歯ブラシ本体、3-1は歯ブラシ部材である。歯ブラシ本体保持具1-1は壁面に取り付けられるものであり、縦長の矩形条の平板部10-1と、平板部10-1の一面の上縁部から直角に突出する保持部11-1と、平板部10-1の下縁部から保持部11-1と同一方向に直角に突出する滴受け12-1とから成る。保持部11-1は、前面に切り欠きを有する横断面略U字状の部材であり、その上面先端部分に、突起11a-1、11b-1を有する。

【0008】 歯ブラシ本体2-1は、筐体20-1と、スイッチ21-1と、筐体20-1内部に収容された図示しない、電池、電動機及び変換機構とから成る。筐体20-1は、保持部11-1に嵌まる程度の外径を有する略円筒状のものであり、一方の端部にはフランジ20a-1を有し、他方の端部にはブラシ取付部20b-1を有する。

【0009】 筐体20-1は、フランジ20a-1側の端部近傍が取り外し可能になっており、そこから電池を装着するものである。この電池には電動機が接続され、電動機の運動は、変換機構によって所要の運動に変換され、ブラシ取付部20b-1に伝達される。スイッチ21-1は電動機の駆動を制御するものであり、筐体20-1のブラシ取付部20b-1寄りの外面に設けられる。歯ブラシ部材3-1は、筐体20-1のブラシ取付部20b-1に取り付けられ、スイッチ21-1を入れることにより歯磨きに必要ブラッシング運動を行うものである。

【0010】 この電動式歯ブラシセットにおいては、歯

磨きをしないときは、歯ブラシ部材3-1が下になるよう、その胴部分を歯ブラシ本体保持部材1-1の保持部11-1の切り欠き部分に嵌め込み、フランジ20a-1を保持部11-1に引っ掛けてぶら下げておく。このとき、フランジ20a-1の前面側には、保持部11-1の上面の突起11a-1、11b-1が引っ掛かり、歯ブラシ本体2-1が歯ブラシ本体保持部材1-1から不用意に脱落しないようになっている。そして、使用するときには、筐体20-1の胴部分を掴んで少し上に持ち上げてから手前に引き出し、スイッチ21-1を指で操作して歯ブラシ部材3-1を運動させ、自分の歯に当てればよい。

【0011】次に、図4及び図5に基づき、第二実施例について説明する。なお、この実施例の構造は、基本的に第一実施例と同様であるので、重複する箇所の説明は省略し、相違点を中心に説明する。図中、1-2は歯ブラシ本体保持具、2-2は歯ブラシ本体、3-2は歯ブラシ部材、4は壁面である。

【0012】歯ブラシ本体保持具1-2は、L字フック状のものであり、壁面4に直接取り付けられる。歯ブラシ本体2-2の筐体20-2の、ブラシ取付部20b-2の反対側の端部には、フランジの代わりに、フック20c-2を有する。この電動式歯ブラシセットにおいては、使用しないときは、フック20c-2を歯ブラシ本体保持具1-2に引っ掛けてぶら下げておくものである。

【0013】なお、本発明の要旨は、歯ブラシ本体を歯ブラシ部材よりも高くなるよう保持し、歯ブラシ部材に付着した水滴等が、歯ブラシ本体の方向に流れ落ちないようにすることであるため、本発明は如上の実施例に限定されるものではなく、例えば、歯ブラシ本体保持具は載置型にしてもよく、また、歯ブラシ本体保持具、歯ブラシ本体及び歯ブラシ部材の形状や、歯ブラシ本体の保持方法は本発明の目的の範囲内で自由に設計変更し得るものであり、本発明はその目的の範囲内において上記の説明から当業者が容易に相当し得る総ての変更実施例を包摂するものである。

【0014】

【発明の効果】本発明に係る電動式歯ブラシセットは如上の如く構成されるので、本発明によるときは、歯ブラシ本体と歯ブラシ部材の間や、歯ブラシ本体の凹凸部等に汚れが溜まり難く、衛生的で、洗浄作業が簡単で、その回数も少なく済む。

【図面の簡単な説明】

【図1】本発明に係る電動式歯ブラシセットの第一実施例を示す正面図である。

【図2】図1に示した電動式歯ブラシセットの側面図である。

【図3】図1に示した歯ブラシ本体保持具の上面図である。

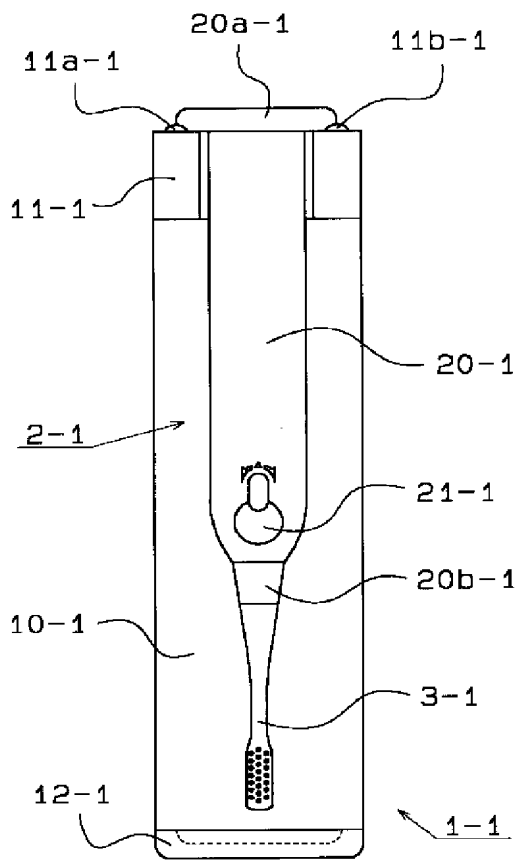
【図4】本発明に係る電動式歯ブラシセットの第二実施例を示す正面図である。

【図5】図4に示した歯ブラシ本体保持具の側面図である。

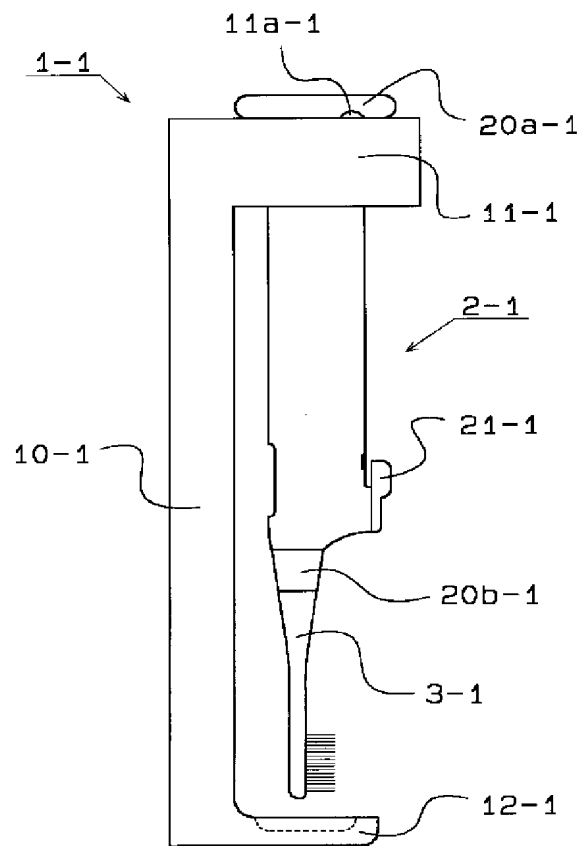
【符号の説明】

1-1・・・歯ブラシ本体保持具
 10-1・・・平板部
 11-1・・・保持部
 11a-1・・・突起
 11b-1・・・突起
 12-1・・・滴受け
 2-1・・・歯ブラシ本体
 20-1・・・筐体
 20a-1・・・フランジ
 20b-1・・・ブラシ取付部
 21-1・・・スイッチ
 3-1・・・歯ブラシ部材
 1-2・・・歯ブラシ本体保持具
 2-2・・・歯ブラシ本体
 20-2・・・筐体
 20b-2・・・ブラシ取付部
 20c-2・・・フック
 3-2・・・歯ブラシ部材
 4・・・壁面

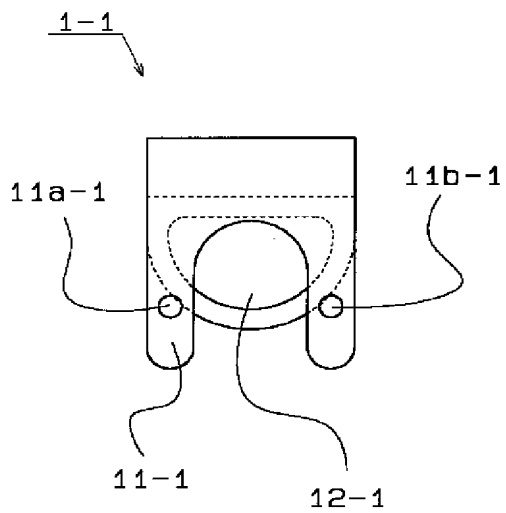
【図1】



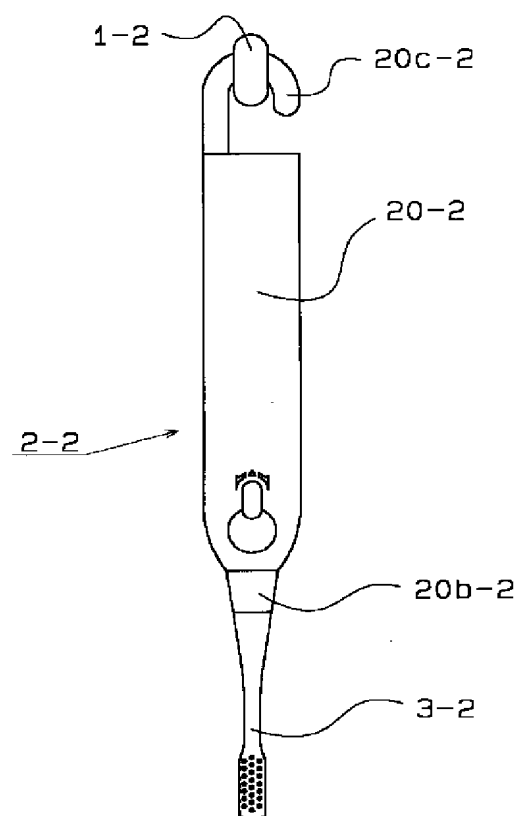
【図2】



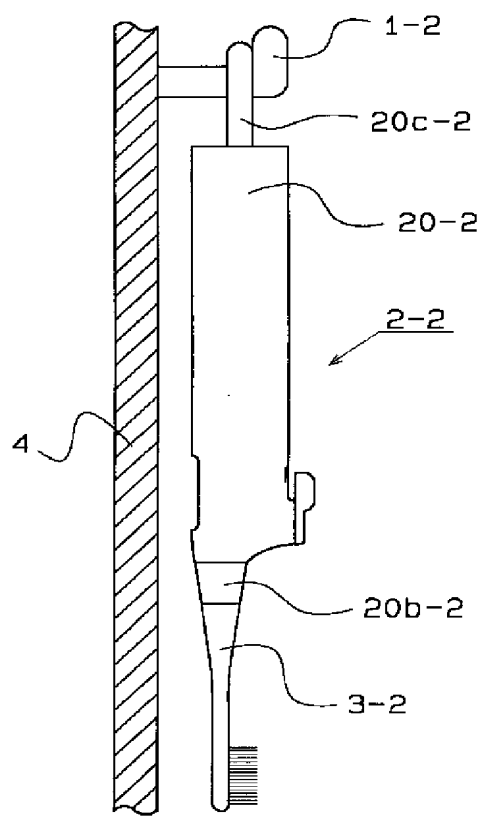
【図3】








【図4】



【図5】

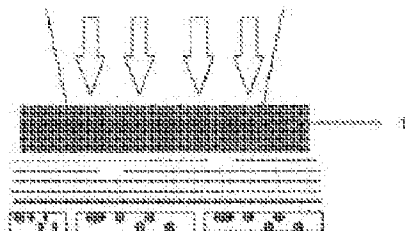


USE OF COMPOUND CONTAINING CHROMOPHORE TO BE APPLIED TO SKIN PRIOR TO LASER TREATMENT**Publication number:** JP10165410 (A)**Publication date:** 1998-06-23**Inventor(s):** MORDON SERGE; SUMIAN CHRYSLAIN; BUFFARD KARINE;
PITRE FRANCK; BOUCLIER MARTINE**Applicant(s):** CIRD GALDERMA**Classification:****- international:** **A61B18/20; A61N5/06; A61N5/067; A61B18/20; A61N5/06;**
A61B18/20; (IPC1-7): A61B17/36; A61N5/06**- European:** A61N5/06C8**Application number:** JP19970334697 19971204**Priority number(s):** FR19960014954 19961205**Also published as:** EP0846477 (A1) US6086580 (A) FR2756741 (A1) CA2222027 (A1) CA2222027 (C)

more >>

Abstract of JP 10165410 (A)

PROBLEM TO BE SOLVED: To provide a compound containing chromophore used to smooth a skin and cut a tissue using a laser which emits light in a visible spectrum area or infrared ray spectrum area. **SOLUTION:** By applying a compound containing chromophore to a skin surface, a light absorption ability is obtained which prevents a laser energy transmitted into the skin from causing unwanted irreversible damage to tissue or cells, and a light energy can be converted into a thermal energy locally at the compound applied.

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(19)日本国特許庁 (J P)

(12) 公 開 特 許 公 報 (A)

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審査請求 有 請求項の数25 O L (全 9 頁)

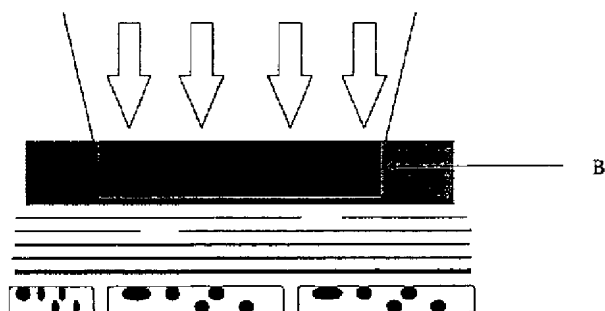
(21)出願番号	特願平9-334697	(71)出願人	594203232 セ・イ・エール・デ・ガルデルマ フランス・06560・ヴァルボンヌ・ソフィ ア・アンティボリス・ルート・デ・ルシオ ール・635
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(54)【発明の名称】 レーザー処理前に皮膚に塗布する組成物における発色団の使用

(57)【要約】

【課題】 可視スペクトル領域または赤外線スペクトルで発光するレーザーを用いて皮膚を滑らかにし、及び組織切除するための発色団を有する組成物を提供する。

【解決手段】 発色団を有する組成物を皮膚表面に塗布することにより、皮膚中に透過したレーザー光エネルギーが組織や細胞に好ましくない不可逆的損傷を生じさせないような吸光度を有し、光エネルギーの熱エネルギーへの変換が塗布された組成物において局所的に達成されることを可能にする。



【特許請求の範囲】

【請求項1】 1つ以上の発色団を含有する組成物を用いて、皮膚表面で光エネルギーを熱エネルギーに変換する方法であって、(1)生理学的に許容可能なキャリアー中に1つ以上の発色団を含有する組成物を上記皮膚表面に塗布し、その際、この組成物および同組成物の塗布厚が、レーザーの発光波長において、皮膚中に透過した光エネルギーが組織や細胞に好ましくない不可逆的損傷を生じさせないような吸光度を有するものであり、(2)レーザー放射線が上記皮膚表面に照射され、同レーザーにより生じた照射により、光エネルギーの熱エネルギーへの変換が塗布された組成物において局所的に達成されることを可能にすることを特徴とする、レーザー放射線の光エネルギーを熱エネルギーに変換する方法。

【請求項2】 レーザー放射線を皮膚表面に照射する前に同皮膚表面に局所的に塗布することを目的とした組成物の製造における1つ以上の発色団の使用であって、レーザーにより生じた照射により、光エネルギーの熱エネルギーへの変換を、塗布された組成物中で局所的に達成することを可能にし、この熱エネルギーにより、上記皮膚表面の下 of 皮膚部分の組織切除を達成することを可能にすることを特徴とする使用。

【請求項3】 上記組成物および同組成物の塗布厚が、皮膚中に透過した光エネルギーが好ましくない不可逆的組織損傷あるいは細胞損傷を生じさせるレーザーの発光波長において吸光度を有することを特徴とする請求項2に記載の使用。

【請求項4】 組織切除目的が、皮膚の非美学的特性、たとえばシワ、スジ、イボ、萎縮した傷跡および／または肥大化した傷跡などの切除であることを特徴とする請求項2あるいは3のいずれか1項に記載の使用。

【請求項5】 組織切除目的が、医学的処置の補完法であって、鼻咽喉腫瘍(rhinophyma)、過角化症、皮膚過増殖、乾癬斑、皮膚癌、光線性角化症、ケロイドなどの皮膚疾患を治療することであることを特徴とする請求項2または3のいずれか1項に記載の使用。

【請求項6】 組織切除目的が、化粧または医薬活性薬剤、特に皮膚科学的活性薬剤の透過性を増大させることであることを特徴とする請求項2または3のいずれか1項に記載の使用。

【請求項7】 熱エネルギーが角質層の組織および表皮の切除のみを達成することを可能にすることを特徴とする請求項2～6のいずれか1項に記載の使用。

【請求項8】 熱効果が放射照度約 10^8 W/cm²未満のレーザーによって得られ、好ましくは放射照度約 10^7 W/cm²以下のレーザーによって得られることを特徴とする請求項2～7のいずれか1項に記載の使用。

【請求項9】 熱効果が、放射照度が 0.5 W/cm²以上、好ましくは 10 W/cm²以上、さらに好ましくは 100 W/cm²以上のレーザーにより得られることを特徴とする請求項

2～8のいずれか1項に記載の使用。

【請求項10】 発色団が、カーボンブラック、グラファイト、鉄黒、ベンガラなどの無機発色団およびメラニン、インドシアニングリーン、染料、またはその他の問題にする波長において、十分な光吸収性を有する不活性化学物質などの有機発色団から選ばれることを特徴とする請求項2～9のいずれか1項に記載の使用。

【請求項11】 発色団が無機発色団であることを特徴とする請求項10記載の使用。

【請求項12】 発色団および／または同発色団を含有する組成物が、発色団が皮膚を透過しないように選択および／または調合したものであることを特徴とする請求項2～11のいずれか1項に記載の使用。

【請求項13】 レーザー光線を照射する前に、組成物、特に皮膜形成性組成物を塗布し、その際、同組成物が、1つ以上の発色団を含有する同組成物上で、用いた波長において光を吸収しないことを特徴とする請求項2～12のいずれか1項に記載の使用。

【請求項14】 可視光線スペクトル領域で発光するレーザー、特に、パルス化色素レーザー(585nm)、ルビーレーザー(694nm)、二重化Nd:YAGレーザー(532nm)などを用いることを特徴とする請求項2～13のいずれか1項に記載の使用。

【請求項15】 赤外線スペクトル領域で発光するレーザー、特に、CO₂(10.6 μ m)、Er:YAG(2.94 μ m)、Ho:YAG(2.12 μ m)、Nd:YAG(1.06 μ m)などのレーザーを用いたことを特徴とする請求項2～13項のいずれかに記載の使用。

【請求項16】 特にシワやスジを減少させることを目的とした美容処置法であって、(1)生理学的に許容可能なキャリアー中に1つ以上の発色団を含有する組成物を上記皮膚表面に塗布し、その際、この組成物および同組成物の塗布厚が、レーザーの発光波長において、皮膚中に透過した光エネルギーが組織や細胞に好ましくない不可逆的損傷を生じさせないような吸光度を有するものであり、(2)レーザー放射線が上記皮膚表面に照射され、同レーザーにより生じた照射により、光エネルギーの熱エネルギーへの変換が塗布された組成物において局所的に達成することを可能とし、かつ同熱エネルギーにより、上記皮膚表面の下 of 皮膚部分の組織切除を可能にすることを特徴とする美容処置法。

【請求項17】 熱エネルギーにより、角質層の組織および表皮切除を達成することを可能にすることを特徴とする請求項16記載の方法。

【請求項18】 熱効果が放射照度約 10^8 W/cm²未満のレーザーにより得られ、好ましくは放射照度約 10^7 W/cm²以下のレーザーにより得られることを特徴とする請求項1または16あるいは17のいずれか1項に記載の方法。

【請求項19】 熱効果が、放射照度 0.5 W/cm²以上、

好ましくは $10\text{W}/\text{cm}^2$ 以上、さらに好ましくは $100\text{W}/\text{cm}^2$ 以上のレーザーにより得られることを特徴とする請求項1または16～18のいずれか1項に記載の方法。

【請求項20】 発色団が、カーボンブラック、グラファイト、鉄黒、ベンガラなどの無機発色団およびメラニン、インドシアニングリーン、染料、その他問題とする波長において、十分な光吸収性を有する不活性化学物質などの有機発色団から選ばれることを特徴とする請求項1または16～19のいずれか1項に記載の方法。

【請求項21】 発色団が無機発色団であることを特徴とする請求項20記載の方法。

【請求項22】 発色団および／または同発色団を含有する組成物が、同発色団が皮膚を透過しないように選択および／または調合されたことを特徴とする請求項1または16～21のいずれか1項に記載の方法。

【請求項23】 レーザー光線を照射する前に、組成物、特に皮膜形成性組成物を塗布し、その際、同組成物が、1つ以上の発色団を含有する同組成物上で用いた波長において光を吸収しないことを特徴とする請求項1または16～22のいずれか1項に記載の方法。

【請求項24】 可視光線スペクトル領域で発光するレーザー、特にパルス化色素レーザー(585nm)、ルビーレーザー(694nm)、二重化Nd:YAGレーザー(532nm)などを用いることを特徴とする請求項1または16～23項のいずれか1項に記載の使用。

【請求項25】 赤外線スペクトル領域で発光するレーザー、特に、 CO_2 ($10.6\mu\text{m}$)、Er:YAG($2.94\mu\text{m}$)、Ho:YAG($2.12\mu\text{m}$)、Nd:YAG($1.06\mu\text{m}$)などのレーザーを用いたことを特徴とする請求項1または16～23のいずれか1項に記載の方法。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】本発明はレーザー処理の前に皮膚に塗布する組成物における発色団の使用に関連する。レーザー処理時に生じた熱効果は、主として組織の切除を生じさせることを目的としている。

【0002】

【従来の技術及び発明が解決しようとする課題】レーザーの放射光と生体組織との間の本質的な相互影響は複雑であり、多数の要因に依存する。現在、皮膚の病理学、皮膚疾患および非美容的特性において、特定タイプのレーザーが必要である。その選択は、本質的に何を目的としているか、そしてどのような効果を生じさせるかによる。

【0003】特に、レーザーの力による皮膚のイニシャル層(真皮の深さまで延びる可能性がある)の切除、または皮膚の平滑化は、赤外線スペクトル領域にあり、主に水に吸収される波長を有するレーザー光線のみを用いて実行される。しかし、皮膚における水の分布は、問題の部位、処理を受ける個々の人の皮膚のタイプおよび年齢

などによって異なる。細胞内での水を標的とした皮膚のキメのレーザー処理は、個人によって再現性がないことは明らかである。赤外線スペクトルで放射し、細胞内での水を標的とするレーザーの例としては、 CO_2 ($10.6\mu\text{m}$)、Er:YAG($2.94\mu\text{m}$)、Ho:YAG($2.12\mu\text{m}$)が含まれるレーザーがある。

【0004】可視光スペクトルまたは近赤外線(波長400nm～1000nm)領域で放射するレーザーは、皮膚に対して深い貫通力を有し、主として色素タイプの生体管の障害の処置に用いられるが、皮膚の平滑化に用いることはできない。可視光スペクトルで発光するレーザー光の例としては、管の障害の処置用のパルス化有色レーザー光(585nm)およびそれと色素障害処理用の二重化Nd:YAGレーザー光が挙げられる。

【0005】光の照射による皮膚の臨牀的、組織学的応答は、用いたレーザー光のタイプと波長により大きく異なる。標的部位には多数の効果が生じる可能性があり、これらの効果は、発色団の性質(与えられた波長の吸光係数、構造、化学組成、等)、単位表面積あたりのエネルギー(または光束)および単位表面積あたりの強さ(照度)に直接依存する。生体組織に対する放射線の相互作用を研究することにより、現われる数種のメカニズムを識別することが可能となる。皮膚科学の分野では、レーザーの使用は、主として2種類のメカニズム、光エネルギーが熱エネルギーに変換される熱効果と、光が衝撃波を生じさせる機械的效果とに基づいて行われる。

【0006】熱効果は、生体組織がレーザー光線によってもたらされた光エネルギーを吸収し、その光エネルギーが熱エネルギー形態で局所的に散逸するによる。与えられた波長によって、生体組織が加熱される度合いは、光束および放射照度に依存する。加熱の強さにより、生体組織を構成する細胞の凝集、炭化、切除などが観察される。レーザーの熱作用は、組織の加熱量及びその時間の長さにより、主として次の3つの効果に分類することができる。

【0007】— 高熱は、適度な温度上昇であり、組織は数分の間に $41\sim 44^\circ\text{C}$ に加熱される。この作用により、膜の消失及び酵素の変性により細胞がダメージを受ける。

— 凝集は、壊死の状態に対応し、直ちに生体組織が破壊されることはない。1秒間の時間スケールで、組織が達する温度は、 $50\sim 100^\circ\text{C}$ である。この作用により、タンパク質およびコラーゲンの変性の結果、組織が収縮し、脱水が起こる。壊死は不可逆的であるが、しかし直ちに物質を失うことはない。

— 切除(ablation)は、物質を失うことに相当する。生体組織の種々の成分が蒸発によって除去される。到達温度は、比較的短時間(1/10秒のスケール)で $100\sim 1000^\circ\text{C}$ となる。 $100\sim 300^\circ\text{C}$ で組織は、液胞破壊による爆発的蒸発により除去される。

【0008】照射域と健康域の間の熱遷移は徐々に起こり、組織学的検討を行うことにより、照射域に最も近い域から最も離れた域へと順に、炭化域または組織切除域(150℃で細胞間炭素が脱離)、凝集域および高温域の3つの区域をわけることができる。

【0009】熱エネルギーが生体組織内で散逸する場合、隣接する組織に熱的損傷が起こるのを抑制するために、レーザー照射時間を熱緩和時間と呼ばれる時間に合わせることが重要であると思われる。物理的観点から考えると、熱緩和時間は、生体組織が過剰温度のうち、初期温度を基準として50%減少させるのに必要な時間である。レーザー照射持続時間がこの緩和時間よりも小さいと、熱は組織内部に拡散することができず、照射された空間部分に閉じ込められたままの状態となる。さらに、この緩和時間内において標的部位に蓄積されるエネルギーが多くなって100℃をはるかに越えるレベルまで温度を上昇させたならば、媒質の局所的蒸発を生じさせる。まだ冷却状態にある組織内部において蒸気泡が膨張すると、振幅の小さな熱弾性波を生じさせる。この選択的光熱分解過程は、たとえば皮膚の血管形成異常の治療に用いられる。すなわち、赤血球がパルスを吸収して爆発、蒸発し、この蒸気が急速に膨張することにより血管が破壊され、血管外溢出が起こる。この技術を表面に用いると、標的組織を局所的に切除することを可能にする。

【0010】さらに、種々の生体組織の吸収スペクトルを研究した結果、放射線の透過する深さは波長に依存することが分かった。したがって、エネルギーの熱形態での散逸は相互作用空間部分内で起こり、この相互作用空間部分は本質的に、照射線の透過深さ(照射域)、影響を受ける組織の拡散係数および熱伝導係数、そして標的部分の局所血管新生と、同標的部分が蓄熱を保持もしくは失う能力に依存する。

【0011】上述のように、熱効果は一般に、約 10^8 W/cm^2 よりも小さな放射照度により得られ、これは、約 10^{-5} s 以上の発光時間に相当する。

【0012】機械的効果は、多量の光エネルギーが十分に小さな領域に十分短い時間で濃縮され、媒質の光学破壊が起こる可能性に基づく。この光学破壊が起こる結果、放射照度が 10^8 W/cm^2 以上の大きな照射により、プラズマ、すなわち広範囲にわたりイオン化された気体が形成される(10^8 W/cm^2 という放射照度は 10^{-7} s 以下の発光時間に相当する。すなわち、熱効果の場合よりも100倍短い持続時間に相当する)。このプラズマの形成には、衝撃波の発生、空洞現象、ジェット形成などが伴う。イオン化媒質(プラズマ)と外部媒質の境界には圧力勾配が生じ、それにより衝撃波が形成され、この衝撃波は隣接組織へと伝達される。この現象(パルス後50~150 nsの間)に続いて、空洞が現れ、すなわち泡が形成され、この空洞は、数百 μs の間に膨張と崩壊(泡がそこで消失)の振動過程による。これらの崩壊の間に、泡中の

圧力が相当に増大するため、新しい衝撃波が放出される。

【0013】最後に、泡が固体壁の近く(例、骨の付近)に発生した場合、それぞれの崩壊現象によりジェットが形成される可能性がある。この場合、ジェットは固体壁の表面損傷(固体の局所侵食)の原因となることがある。

【0014】したがって、米国特許第5,423,803号は、赤外線スペクトル領域(Nd:YAG, 1064nm; CO_2 , 10.6 μm)で発光し、50ns以下の発光時間を有するレーザーを用いて、人間の皮膚から角質層の一部を切除する方法について記述している。レーザー照射前、発色団を含有する組成物を処置対象の皮膚に塗布する。超音波かレーザーのいずれかを用いて、これらの発色団を角質層の細胞内空間の中に入れる。続いてこの皮膚の処理部分に、発色団をイオン化する(光学破壊後)のに十分なエネルギーをもったレーザー光線を照射する。上述のように、発色団がイオン化される結果、角質層の最初の3つの細胞レベルの切除の原因となる衝撃波(機械的効果)が形成される。この効果は衝撃波の放出に基づいているため、処理しようとする部分に隣接する組織に好ましくない不可逆的損傷を引き起こすという欠点がある。さらには、この処理の有効性は、発色団の角質層中への透過により空間的、質的に制限される。

【0015】本発明の目的の一つは、可視スペクトル領域で発光するレーザーを用いて皮膚を滑らかにすることを可能にすることである。

【0016】本発明のもう一つの目的は、赤外線スペクトル領域で発光するレーザーを用いて皮膚を滑らかにする処理を再現性のあるものとするすることである。

【0017】もう一つの目的は、好ましくない不可逆的損傷の形成を回避する処理法を提供することにある。

【0018】

【課題を解決するための手段】これらの目的やその他の目的は本発明により達成される。本発明は、1つ以上の発色団を含有する組成物を用いて、皮膚表面において、レーザー放射線光エネルギーを熱エネルギーに変換する方法であって、(1)生理学的に許容可能なキャリアー中に1つ以上の発色団を含有する組成物を上記皮膚表面に塗布し、その際、この組成物および同組成物の塗布厚が、レーザーの発光波長において、皮膚中に透過した光エネルギーが組織や細胞に好ましくない不可逆的損傷を生じさせないような吸光度を有するものであり、(2)レーザー放射線が上記の皮膚表面に照射され、同レーザーにより生じた照射により、光エネルギーの熱エネルギーへの変換が塗布された組成物において局所的に達成されることを可能にすることを特徴とする、レーザー放射線の光エネルギーを熱エネルギーに変換する方法に関連する。

【0019】特に、1回のレーザーショットの間に組成物中に生じる熱エネルギーは、皮膚内部の熱伝導によっ

て伝わり、局所的に温度を100℃以上に増大させ、組織切除を達成することが可能となる。

【0020】したがって、本発明はさらに、レーザー放射線を上記皮膚表面に照射する前に皮膚表面に局所的に塗布することを目的とした組成物の製造における1つ以上の発色団の使用であって、レーザーにより生じた照射により、塗布された組成物中において局所的な光エネルギーの熱エネルギーへの変換達成を可能にし、この熱エネルギーにより、上記皮膚表面の下にある皮膚の組織切除達成を可能にするような、発色団の利用にも関わる。

【0021】レーザーの発光波長に吸光度をもったこの組成物とその塗布厚は、皮膚中に透過する光エネルギーにより好ましくない不可逆的な組織損傷あるいは細胞損傷を生じさせないようなものであることが好ましい。

【0022】組織切除の後、より若々しい、および／または優美さに欠ける点の改善された新生の皮膚の形成が可能となり、このことは皮膚を滑らかにすることに相当する。さらに具体的にいうと、この方法によれば、皮膚の非美的特性、たとえばシワ、スジ、イボ、萎縮した傷跡および／または肥大化した傷跡などを除去することができる。さらに、この処理法は、例えば、鼻咽腫瘍(rhinophyma)、過角化症、皮膚過増殖、乾癬斑、皮膚癌、光線角化症、ケロイドなどの皮膚病状の治療のための医学的処理法そのもの、もしくはその補完法として使用することができる。

【0023】さらには、組織切除は、化粧品あるいは医薬品、特に皮膚科学的活性薬剤の浸透を増大させることを可能にする。この場合、照射後かつ新生皮膚の完全形成前に、1種類以上の活性薬剤を含有する化粧品または医薬品組成物が塗布される。活性薬剤の実例としては、局所および／または全身投与を目的とした医薬品として経皮的に使用される活性薬剤、特に、レチノイン酸、同酸誘導体(レチノイド類)、過酸化ベンゾイル、抗生物質、コルチコステロイド、抗菌剤、ビタミンD3、D2およびその誘導体が挙げられる。

【0024】本発明はさらに、美容的処置法、特にシワやスジを減少させる美容的処置法であって、(1)生理学的に許容可能なキャリアー中に1つ以上の発色団を含有する組成物を上記皮膚表面に塗布し、その際、この組成物および同組成物の塗布厚が、レーザーの発光波長において、皮膚中に透過した光エネルギーが組織や細胞に好ましくない不可逆的損傷を生じさせないような吸光度を有するものであり、(2)レーザー放射線が上記皮膚表面に照射され、同レーザーにより生じた照射により、光エネルギーの熱エネルギーへの変換が塗布された組成物において局所的に達成されることを可能にし、かつこの熱エネルギーにより、上記表面の下にある皮膚部分の組織切除を達成することを可能にすることを特徴とする美容的処置法に関連する。

【0025】熱効果は光エネルギーの熱エネルギーへの

変換に対応する上述のような効果である。したがって、この熱効果は一般に、放射照度がおよそ 10^3 W/cm²よりも小さなレーザーにより得られ、この放射照度は、約 10^{-5} s以上の発光時間に相当する。この効果は、好適には放射照度が約 10^7 W/cm²以下のレーザーにより達成される。

【0026】放射照度は、好ましくは0.5 W/cm²以上であり、より好ましくは10 W/cm²以上、さらに好ましくは100 W/cm²以上である。

【0027】発光時間は、好ましくは100 s以下であり、さらに好ましくは10 s以下である。

【0028】かくしてレーザーにより放出された光エネルギーは、皮膚に塗布された組成物中において、同組成物中に存在する発色団により吸収され、熱エネルギーに変換される。

【0029】好適には、この熱エネルギーで、角質層の組織および表皮の切除のみすることを可能にする。これらの条件下では、上述のように、皮膚への熱エネルギーの伝達によって、真皮において凝集が起ころても、または起ころなくてもよい。処置方法によっては、例えば、活性薬剤の透過力を増大させれば、superficial dermisを凝集させなくて済む。

【0030】本発明に使用する発色団は、好適に、同発色団を含む組成物にレーザーの発光波長において、皮膚中に透過した光エネルギーが好ましくない不可逆的組織損傷あるいは細胞損傷を生じさせないような吸光度を付与するような発色団とする。特に、発色団の使用には、カーボンブラック、グラファイト、鉄黒、ベンガラなどの無機発色団や、メラニン、インドシアニングリーン、染料、その他問題にする波長において十分な吸光度を有する不活性化化学物質(たとえば1064nmにおいては、ケイ素誘導体、コレステロール誘導体、リン酸塩、硫酸塩など)などの有機発色団の使用などが考えられる。好適には無機発色団を用いる。

【0031】これらの発色団は、油性および／または水性支持体(エマルジョン、ゲル、軟膏、ポリマーを分散した物、泡状物、エアゾール、懸濁物などが液体媒質中に含まれた形態で、成膜性を有してもよく、エアゾールの形態で存在していてもよい)中に分散させるまたは任意のタイプの生理学的に許容可能なキャリアー中に溶解させることができる。

【0032】これらの発色団および／または同発色団を含有する組成物は、好ましくは発色団が皮膚を透過しないように選択および／または調合する。したがって、発色団は、皮膚を透過しないような適当な粒径を有するか、または組成物がこれらの発色団を凝集体の形態で含有させ、発色団が皮膚を透過しないようにすることができる。

【0033】好ましくない不可逆的組織損傷あるいは細胞損傷は、真皮における毛細血管が損傷され、特に、へ

モグロビンの凝集が起こり、またはメラノサイト、ランゲルハンス細胞、ケラチノサイト、繊維芽細胞、特にこれらの細胞の前駆体が不可逆的に破壊され、さらにこれらの細胞または前駆体中に含まれる水、メラニン、タンパク質などの内因的な発色団の切除により損傷される。

【0034】可視光線および赤外線スペクトル領域で発光するタイプのレーザーは、熱効果を生じさせることを可能にするようなレーザーであればすべて(2)で使用する事ができる。可視光線スペクトル領域で発光するレーザーにはパルス化色素レーザー(585nm)、ルビーレーザー(694nm)および二重Nd:YAGレーザー(532nm)があり、赤外線スペクトル領域で発光するレーザーとしては、CO₂(10.6μm)、Er:YAG(2.94μm)、Ho:YAG(2.12μm)、Nd:YAG(1.06μm)レーザーなどがある。

【0035】組成物と、同組成物が皮膚表面に塗布された塗布厚の吸光度は、組成物の物理化学的特性と合わせて、レーザーの発光波長に依存する。特に、同吸光度は、発色団のタイプ、同粒径、同発色団製品の分散物の品質、同組成物の濃度および組成などによって変化し、したがって、たとえばカーボンブラックを2.5%で配合した場合、ある種の条件下では0.25%の組成物と同じ吸収スペクトルは示さない。

【0036】したがって、与えられたキャリアー中、与えられた色素濃度において、同一実験条件の下では、色素の分散物の品質が向上すると(トリシリンダー、ultra turaxの使用、色素ペースト通過処理など)、光吸収性が向上する。

【0037】可視光線スペクトル領域または近赤外線スペクトル領域(波長、1μm以下)で発光するレーザーの場合、1つ以上の発色団を含み、レーザー放射線と皮膚の間に配置された組成物により、これらの波長において光を吸収する主たる内因的な発色団であるメラニン、ヘモグロビン、オキシヘモグロビンをレーザー照射から保護することができる。したがって、組織の切除が行われると同時に、真皮の内因的な化合物を保護する。組織の切除は、本発明の組成物の使用、皮膚表面に同組成物の塗布厚、そして当然のことながら使用するレーザーのパラメータのみに依存する。

【0038】赤外線スペクトル領域(波長、1μm以上)で発光するレーザーの場合、1つ以上の外因的な発色団を含み、レーザー放射線と皮膚の間に配置された組成物により、皮膚上に得られる結果が、もはや組織中に含まれる水の分布に依存しないものとする事が可能となる。実際、これらの組織中の水の分布は、問題の部位と、処置を受ける患者の年齢および皮膚のタイプの双方に依存する。したがって、得られた結果は、主として発明にしたがって使用した組成物と皮膚表面に同組成物の塗布厚、そして当然のことながら使用するレーザーのパラメータ

にのみ依存する。

【0039】したがって、与えられた処理(一定の物質の損失と到達深さ)について、特定のレーザーのユーザーの場合、放射照度および光束を、組成物および同組成物を皮膚表面に塗布の厚さの関数として定義することにより、上述の結果が達成される。

【0040】図1〜6は本発明をさらに明らかに示したものであるが、これらの図は、本発明を限定するものではない。これらの図は、ヌードラットの皮膚を図式的に表したものである。

【0041】さらに具体的にいうと、放射照度および光束は、レーザー照射の持続時間が、処理対象の皮膚の熱緩和時間よりも短くなるように選択される。そうすると、熱は皮膚内部に拡散することができ、かつ小さな空間部分に限定されたままの状態となり、組織切除の選択性が高まる。

【0042】組成物、特に膜形成組成物(塗布後乾燥する組成物)は、本発明にしたがって使用される組成物上で用いる波長において光吸収を示さないものであるが、レーザー放射線の照射を行う前に好適に塗布することができる。この添加の目的は、放出されるエネルギーをより小さな相互作用空間部分に限定し、組織切除中に放出される熱弾性波を増幅することにある。したがって、最小の光エネルギーで、隣接組織中に生じる損傷を抑制しながら、組織切除を行うことができる。

【0043】本発明の具体的な実施態様によれば、レーザーは、上記皮膚表面を均一かつ再現性よく処置することを可能にするために、レーザーを皮膚に照射するレーザー光線領域に対応する領域よりも広い領域にわたって移動させることのできる装置に接続してもよい。使用する装置は、具体的には米国特許第5,330,517号記載の装置とすることができる。

【0044】

【実施例】ここで、例示により説明するための、ただしなんら発明を制限するものではないが、いくつかの実施例を示す。上記および下記に示す割合は、特に断らない限り、重量%である。

【0045】実施例1：

ベンガラ(5%)をベースとするO/Wエマルジョン

成分	%
Lanol CTO (Seppic)	
セチルステアリルアルコール	7
Geleol (Gattefosse)	
ステアリン酸グリセリル	2
セチルアルコール	1.5
DC 200、300 cp	
ポリジメチルシロキサン	1.5
Polysynlane (NOF)	
水素化イソパラフィン	15.1
Sicovit red 30E172 (BASF)	
ベンガラ	5
グリセロール	20.1
水	47.8

【0046】実施例2:

カーボンブラック(2.5%)をベースとする水性ゲル

成分	%
Derussol A (Degussa)	
カーボンブラック水性分散液	16.65
水	72.85
Aerosil 200 (Degussa)	7.5
プロピレングリコール	2
Poloxamer 182	1

【0047】実施例3:

カーボンブラック(2.5%)をベースとする軟膏

成分	%
FW1 (Degussa)	
カーボンブラック	2.5
Polysynlane (NOF)	19.4
適当な親油性分散剤	0.63
石油ジェリー状製剤	77.47

【0048】実施例4:

カーボンブラック(2.28%)をベースとする皮膜形成性溶液

成分	%
Derussol A (Degussa)	15.2
Eudragit NE 30 D (Rohm & Haas)	34.7
水	50.1

【0049】実施例5:

処置例: 皮膚を滑らかにする処理。

【0050】医薬製剤を添加することによる皮膚を滑らかにする方法は、図1～6により説明することができる。図1は、ヌードラットの表皮および真皮の構造の概略を示したものである。

【0051】医薬製剤の塗布: ヌードラットの皮膚表面(角質層上)に局所的塗布を行う。組成物中に含まれる発色団は角質層上にとどまり、皮膚中には分配されない(図2)。

【0052】レーザー照射: 次の段階は、発光時間が1 μ sより長い二重化Nd:YAGレーザー(532nm)を用い

て、皮膚表面に照射を行うことからなる(図3)。用いる機構が熱効果なので、放射照度は 10^7 W/cm²以下とする。適用する組成物(実施例1、2に示した組成物)および同組成物の塗布厚は、組織(表皮、真皮)中に透過した光エネルギーが、不可逆的組織損傷あるいは細胞損傷を生じさせるのに十分な量とならないような吸光度を有するものとする。この組成物をレーザー放射線と皮膚の間に配置すれば、血管中のオキシヘモグロビンやヘモグロビンとともに、表皮中のメラニンも照射から保護される。

【0053】組成物を十分な厚さ(実施例1、2で挙げた組成物の場合は約100 μ m)まで塗布すると、同組成物

中に含まれる発色団により吸収される光エネルギーは、局所的に(同組成物内で)熱エネルギーに変換される(図4)。1回のレーザーショットの間に組成物中に生成された熱は、皮膚内部の熱伝導により伝わり(図5)、温度を局所的に100℃以上まで増大させ、組織切除を達成する(図6)。

【0054】さらに具体的にいうと、実施例2記載の組成物をヌードラットの皮膚表面に厚さおよそ100 μ mまで塗布した場合、放射照度450W/cm²および光束25J/cm²で照射することにより、superficial dermisを25~50 μ mまで凝集させ、同時に表皮から基底層まで切除することができる。8~10日後、このヌードラットの皮膚は、瘢痕形成により再生される。角質層も、皮膚の残りの部分と同様に、瘢痕形成現象により回復する。

【0055】他の外因的発色団を使用して角質層に塗布された組成物の照射条件を変え、前実施例と同様の結果を得ることができる。例を挙げると、実施例1記載の組成物を使用した場合、同じ放射照度(450W/cm²)が必要であるが、同一の結果を得るためには2倍近い光束が必要となる。

【図面の簡単な説明】

【図1】 ヌードラットの表皮及び真皮の構造の概略図

である。

【図2】 実施例5に示した方法の第一段階(1)を示す図である。図示したように、発色団を含有する組成物Aを皮膚表面に塗布する。

【図3】 実施例5に示した方法の第二段階(2)を示す図である。レーザーを使って光放射線を照射する。

【図4】 実施例5において、皮膚表面に塗布された組成物と光エネルギーの相互作用空間部分Bを示す図である。同空間部分Bにおいて光エネルギーが熱エネルギーに変換される。

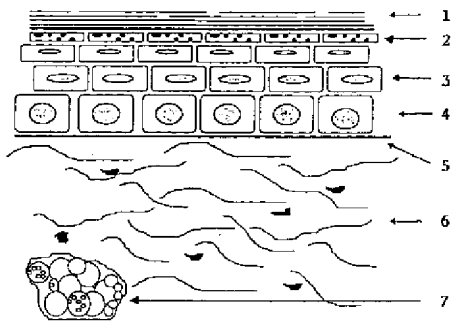
【図5】 実施例5において、熱伝導により加熱される空間部分C(斜線部分)を表す図である。

【図6】 実施例5において、皮膚の組織切除を示す図である。この切除は基底膜まで続く。

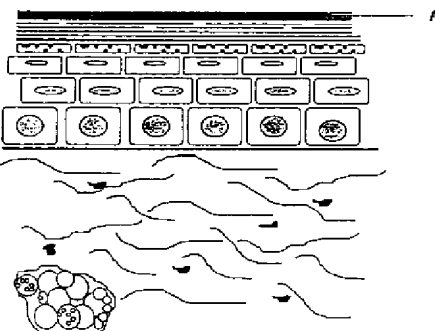
【符号の説明】

- 1：角質層
- 2：顆粒層
- 3：有棘層
- 4：基底層
- 5：基底膜
- 6：真皮
- 7：真皮中の皮脂腺

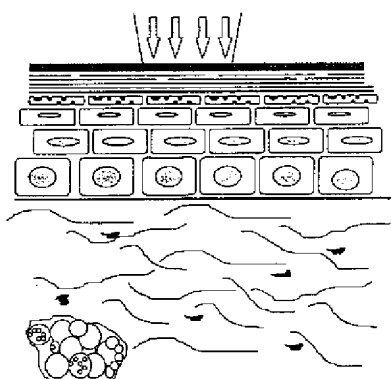
【図1】



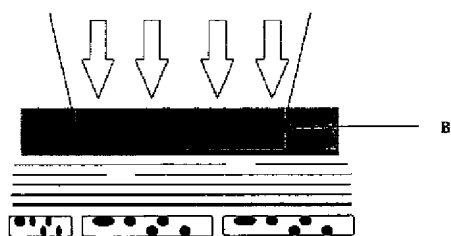
【図2】



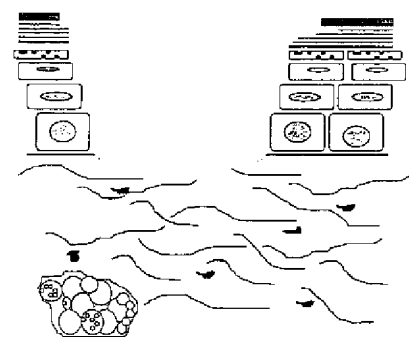
【図3】



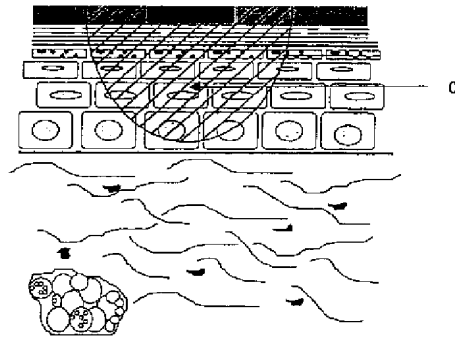
【図4】



【図6】



【図 5】



フロントページの続き

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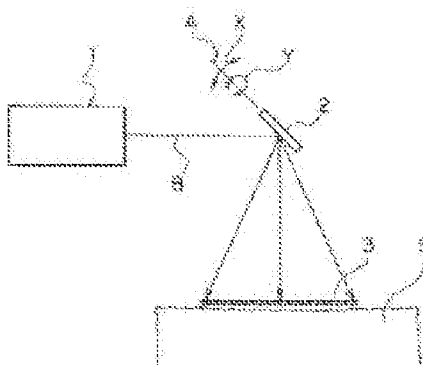
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LASER APPLICATION DEVICE FOR SKIN TREATMENT**Publication number:** JP11047146 (A)**Publication date:** 1999-02-23**Inventor(s):** UTSUKI RYUICHI**Applicant(s):** UTSUKI RYUICHI**Classification:****- international:** **A61B18/20; A61N5/06; A61B18/20; A61N5/06;** (IPC1-7): A61B17/36; A61N5/06**- European:****Application number:** JP19970206435 19970731**Priority number(s):** JP19970206435 19970731**Also published as:**

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Abstract of JP 11047146 (A)

PROBLEM TO BE SOLVED: To easily perform treatments such that parts requiring different cauterization levels are juxtaposed. **SOLUTION:** A laser application device has a beam scan means 2 applying a laser beam to the area for cauterization by scanning, and has a cauterization control means 3 for juxtaposing a first cauterization level part where cauterization depth in the skin is great and a second cauterization level part where the cauterization level is shallower than in the first cauterization level part, or an uncauterized part, during the application of the laser beam in the scanning fashion.



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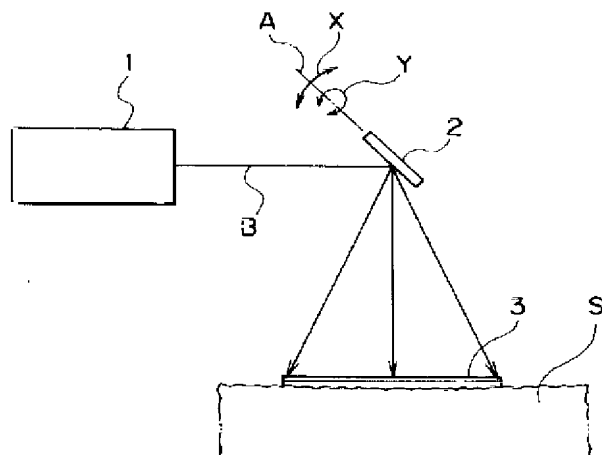
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(54) 【発明の名称】 皮膚治療用のレーザー照射装置

(57) 【要約】

【課題】 焼灼レベルの異なる部分を混在させる治療を簡単に行なうことのできる皮膚治療用のレーザー照射装置の提供。

【解決手段】 レーザ照射装置は、焼灼対象領域に対し走査的にレーザービームを照射するビーム走査手段2を備えるとともに、走査的なレーザービームの照射に際して、皮膚に対する焼灼深さが深い第1の焼灼レベル部分と、この第1の焼灼レベル部分より浅い焼灼レベルの第2の焼灼レベル部分または非焼灼部分とを混在させるための焼灼制御手段3を備えている。



【特許請求の範囲】

【請求項1】 皮膚の所定領域に焼灼を施す治療に用いるレーザ照射装置において、焼灼対象領域に対し走査的にレーザビームを照射するためのビーム走査手段を備えるとともに、走査的なレーザビームの照射に際して、皮膚に対する焼灼深さが深い第1の焼灼レベル部分と、この第1の焼灼レベル部分より浅い焼灼レベルの第2の焼灼レベル部分または非焼灼部分とを混在させるための焼灼制御手段を備えたことを特徴とするレーザ照射装置。

【請求項2】 焼灼制御手段は、レーザ光に対する透明性の高い第1の透明レベル部と、この第1の透明レベル部より透明性の低い第2の透明レベル部を所定のパターンで有するマスクである請求項1に記載のレーザ照射装置。

【請求項3】 焼灼制御手段は、レーザビームをパルス化し、且つ各パルスのパワーを所定のパターンで異ならせる制御をなすようになっている請求項1に記載のレーザ照射装置。

【請求項4】 焼灼制御手段は、レーザビームに中抜け的なプロファイルを与えると同時に、この中抜け状態のレーザビームを断続的に照射する制御をなすようになっている請求項1に記載のレーザ照射装置。

【発明の詳細な説明】**【0001】**

【発明の属する技術分野】本発明は、例えばしわ取り治療などのように、皮膚の所定領域に焼灼を施す治療に用いるレーザ照射装置に関する。

【0002】

【発明の背景】レーザビームの照射により皮膚を治療することが広く行なわれている。その一つとしてしわ（皺）取り治療がある。しわ取り治療は、レーザビームの照射で皮膚の特定領域を一定の深さで焼灼することにより行なわれる。しわ取り治療の効果は、基本的には、皮膚をレーザビームで焼灼する深さに左右され、焼灼深度が深いほど効果的な治療ができる。しかし深い焼灼は、皮膚の再生治療を遅延させ、瘢痕形成や色素沈着、色素脱失の原因となる。このため、焼灼の深さには限界があり、十分な治療効果が得られないという問題があった。

【0003】またこのようなしわ取り治療は、白色人種系の人についてその例が多く、有色人種系の人については比較的少ない。その理由は、有色人種の皮膚が元来、白色人種よりもレーザ照射後の色素沈着、色素脱失、瘢痕などを来たしやすく、皮膚そのものが厚いということにも関係していると考えられる。すなわち白色人種系の人、比較的皮膚が薄いため、浅く焼灼するだけでも有効なしわ取り効果を得ることができる。一方、有色人種系の人、比較的皮膚が厚く、有効なしわ取りとするにはかなり深く焼灼する必要がある。そのため深い焼灼に伴う色素沈着や瘢痕などが残る可能性が大きく、このこ

とが有色人種系の人にしわ取り治療を施す上で大きな障害となっている。

【0004】このような事情から本願発明者は、出来るだけ深く焼灼できて、なお且つ色素沈着や瘢痕などを残す可能性の小さい治療法について研究を重ねて来た。その結果、有効なしわ取り効果を得るには、真皮に達するレベルの焼灼を基本的に必要とするものの、このレベルの焼灼は焼灼しようとする領域全体に必ずしも均一にある必要のないことを見出した。つまり本願発明者の新たな知見によると、浅いレベルの焼灼部分や非焼灼部分が深いレベルの焼灼部分に混じって散在するようにしても、十分に有効なしわ取り効果を得ることが可能であり、しかもこのように浅いレベルの焼灼部分や非焼灼部分を深いレベルの焼灼部分に混在させることで、表皮の基底層による再生能力を残存させることができ、瘢痕や色素沈着、色素脱失の発生を効果的に防止することもできる。

【0005】

【発明が解決しようとする課題】上記のような焼灼レベルの異なる部分を混在させる治療法は、これを簡単に行なうことのできるレーザ照射装置を実現することで初めて効果的に施すことができる。したがって本発明の目的は、そのような皮膚治療用のレーザ照射装置の提供にある。

【0006】

【課題を解決するための手段】本発明によるレーザ照射装置は、皮膚の所定領域に焼灼を施す治療に用いるものであり、焼灼対象領域に対し走査的にレーザビームを照射するためのビーム走査手段を備えるとともに、走査的なレーザビームの照射に際して、皮膚に対する焼灼深さが深い第1の焼灼レベル部分と、この第1の焼灼レベル部分より浅い焼灼レベルの第2の焼灼レベル部分または非焼灼部分とを混在させるための焼灼制御手段を備えている。

【0007】このレーザ照射装置によると、例えばコンピュータなどにより設定した領域に対しビーム走査手段により自動的にレーザビームを走査させることで、目的の焼灼領域に対しレーザビームを照射することができる。しかもこの走査的な照射に際して、焼灼制御手段により、第1の焼灼レベル部分（深いレベルの焼灼部分）の間に第2の焼灼レベル部分（浅いレベル焼灼部分）や非焼灼部分を自動的に混ぜ込ませることができる。このため上記のような治療法による治療を容易に施すことが可能となる。

【0008】このようなレーザ照射装置によりしわ取り治療を行なう場合には、第1の焼灼レベルは、少なくとも真皮に達するレベルとし、第2の焼灼レベルは表皮の基底層に達することのない深さ以下とするのが好ましい。

【0009】上記のようなレーザ照射装置における焼灼

制御手段には種々の方式が可能である。好ましい方式としては、マスク方式やパルス方式あるいはビームプロファイル方式などがある。マスク方式は、レーザ光に対する透明性の高い第1の透明レベル部と、この第1の透明レベル部より透明性の低い第2の透明レベル部を所定のパターンで有するマスクを用いることで、第1の焼灼レベル部分と第2の焼灼レベル部分または非焼灼部分との混在を与える方式である。この場合、第1の透明レベル部はレーザ光に対し完全に透明にするのが通常である。一方、第2の透明レベル部は、完全に不透明とするか、または適度な透過性を与えるようにする。第2の透明レベル部を完全不透明とする場合には、第1の焼灼レベル部分と非焼灼部分とが混在することになり、第2の透明レベル部に適度な透過性を与える場合には、第1の焼灼レベル部分と第2の焼灼レベル部分とが混在することになる。

【0010】パルス方式は、レーザビームをパルス化し、且つ各パルスのパワーを所定のパターンで異ならせる制御、つまりパワーの異なるレーザビームを所定の繰り返しパターンで断続的に照射する制御をなすことで、第1の焼灼レベル部分と第2の焼灼レベル部分または非焼灼部分との混在を与える方式である。この方式では、第1の焼灼レベル部分を与えるパワーのパルスのみを一定間隔で照射することにより、第1の焼灼レベル部分と非焼灼部分を混在させることができる。また第1の焼灼レベル部分を与えるパワーのパルスと、これよりもパワーの小さいパルスとを組み合わせる照射することにより、第1の焼灼レベル部分と第2の焼灼レベル部分とを混在させることができる。

【0011】ビームプロファイル方式は、レーザビームに例えばドーナツ状のように中心部分が抜ける中抜け的なプロファイルを与え、この中抜け状態のレーザビームを断続的に照射する制御をなすことで、第1の焼灼レベル部分と第2の焼灼レベル部分または非焼灼部分との混在を与える方式である。そのプロファイルにおける中抜け状態は、中心部分のパワーを周辺部のパワーよりも小さくすることで与える。つまり中心部分のパワー P_c が周辺部のパワー P_s に対し $0 \leq P_c < P_s$ となるようにする。

【0012】

【実施の形態】以下本発明の実施形態について説明する。第1の実施形態によるレーザ照射装置は、マスク方式の焼灼制御手段を備えたタイプである。その構成を図1に模式化して示す。図1に見られるようにレーザ照射装置は、レーザ発振ユニット1、ビーム走査手段であるミラー2、及びマスク3を備える。レーザ発振ユニット1から射出したレーザビームBは、ミラー2で反射した後、マスク3を介して皮膚Sを照射する。ミラー2は、図示せぬコンピュータなどによる制御の下でミラー2の中心軸Aに対する矢印Xや矢印Yの如き回動を行ない、

これに応じてレーザビームBを目的の焼灼領域にジグザグ的走査で照射する。

【0013】マスク3は、図2にその一例を示すように、レーザ光に対し完全に透明である第1の透明レベル部3aと完全に不透明であるか、または適度な透過性を与えた第2の透明レベル部3bを交互的に配したパターンに形成することができる。このようなマスク3は、レーザ光に対し完全に透明である基材に不透明化処理を施したり、あるいはレーザ光に対し完全に不透明である基材を切り抜くなどして形成することができる。

【0014】第2の実施形態によるレーザ照射装置は、パルス方式の焼灼制御手段を備えたタイプであり、図3に示すように、レーザ発振ユニット1にパルス制御手段5を接続してある。パルス制御手段5は、レーザ発振ユニット1を制御してレーザビームBをパルス化するとともに、各パルスのパワーを所定のパターンで異ならせる。そのパルスパターンの例を図4に示す。図4の

(a)は、第1の焼灼レベルを与えるパワーのパルスのみを一定間隔で照射するパターンであり、図4の(b)は、第1の焼灼レベルを与えるパワーのパルスと、これよりもパワーの小さいパルスとを組み合わせるパターンである。

【0015】第3の実施形態によるレーザ照射装置は、ビームプロファイル方式の焼灼制御手段を備えたタイプであり、図5に示すように、レーザ発振ユニット1とミラー2の間にプロファイル形成手段6を備えており、このプロファイル形成手段6によりレーザビームBに所定のプロファイルを与える。そのプロファイルは、図6に一例を示すように、中抜け状態とする(図中にハッチングを施した部分がパワー零の部分である)。また発振制御手段7を備えており、レーザビームBを断続的に照射する制御を行なう。このようなレーザ照射装置による焼灼のパターンは図7に示すようになる。図中の○が非焼灼部分である。

【0016】以上の実施形態ではビーム走査手段にミラーを用いてジグザグ的走査をなさせるようにしていたが、この他にも例えばレンズなどを用いてラセン的走査などを行なわせることも可能である。

【0017】

【発明の効果】以上説明したように、本発明によると、非焼灼または浅い焼灼レベルの部分と混在させることで、従来の均一に焼灼する方法よりも、速やかに皮膚の再生治癒が得られる。このため治癒時間が遅延することなく、より深い焼灼が可能となり、より治療効果の高いしわ取り治療を行なうことができる。また速やかな治癒は、色素沈着、色素脱失、瘢痕形成などを来す可能性がより少なくなり、例えば皮膚の厚い人や色素沈着を来しやすい有色人種系の人にもしわ取り治療を施しやすくなる。

【図面の簡単な説明】

【図1】第1の実施形態によるレーザ照射装置の構成図。

【図2】マスクの平面図。

【図3】第2の実施形態によるレーザ照射装置の構成図。

【図4】パルスパターンの説明図。

【図5】第3の実施形態によるレーザ照射装置の構成図。

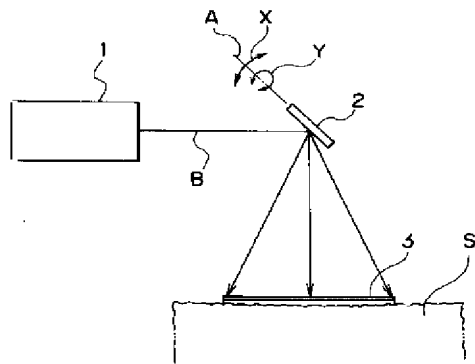
【図6】レーザビームのプロファイルの説明図。

【図7】第3の実施形態によるレーザ照射装置による焼灼のパターンの説明図。

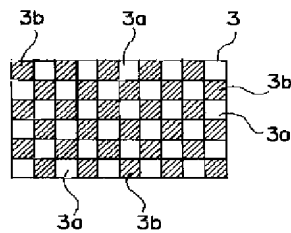
【符号の説明】

- 1 レーザ発振ユニット
- 2 ミラー（ビーム走査手段）
- 3 マスク
- 5 パルス制御手段
- 6 プロファイル形成手段
- 7 発振制御手段

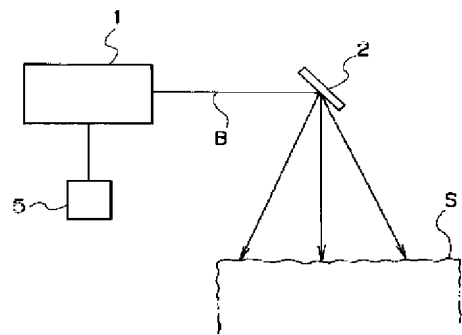
【図1】



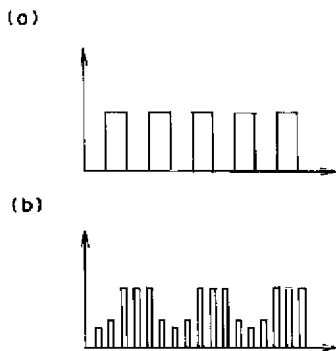
【図2】



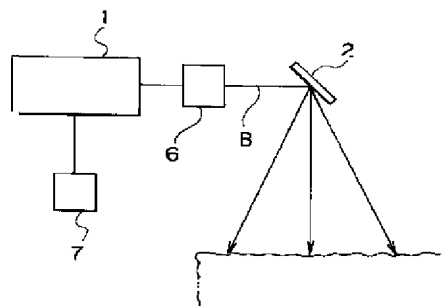
【図3】



【図4】



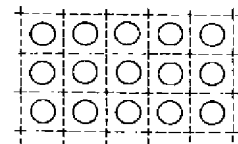
【図5】



【図6】

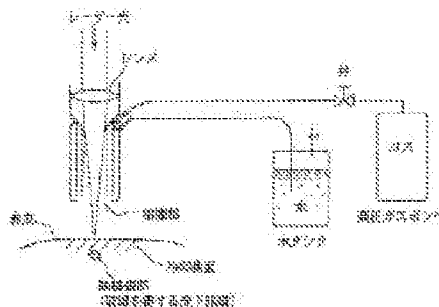


【図7】



FRONT SURFACE COOLING METHOD AT THE TIME OF LASER IRRADIATION**Publication number:** JP2000037400 (A)**Publication date:** 2000-02-08**Inventor(s):** KANEDA MICHIIRO**Applicant(s):** NIPPON SEKIGAISEN KOGYO KK**Classification:****- international:** **A61B18/20; A61N5/06; H01S3/041; A61B18/20; A61N5/06; H01S3/04; (IPC1-7): A61B18/20; A61N5/06; H01S3/041****- European:****Application number:** JP19980225383 19980723**Priority number(s):** JP19980225383 19980723**Abstract of JP 2000037400 (A)**

PROBLEM TO BE SOLVED: To obtain an efficient and easy front surface cooling method at the time of a laser irradiation. **SOLUTION:** In a method for destroying a specified subcutaneous tissue and medically treating it by the irradiation of a laser beam, a mist-state liquid is sprayed to an epidermis above the subcutaneous tissue and also gas is blown so that the vaporization of the liquid is promoted and the heat of the epidermis is taken away by the heat of vaporization. Then, the epidermis is cooled.



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4C082 RA02 RG06

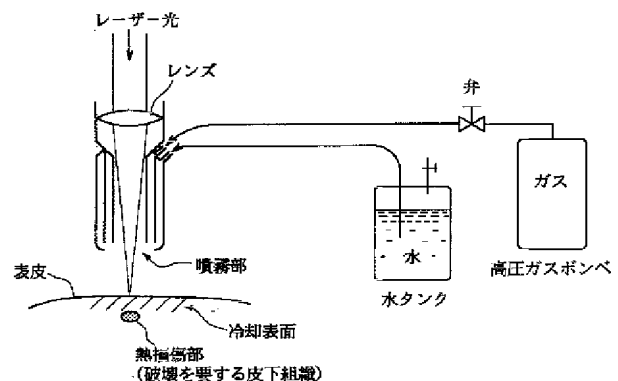
5F072 HH09 YY01

(54) 【発明の名称】 レーザー照射時の表面冷却方法

(57) 【要約】

【課題】 効率的で且つ簡便なレーザー照射時の表面冷却方法を得る。

【解決手段】 レーザー光の照射によって特定の皮下組織を破壊し治療を行う方法において、該皮下組織上の表皮に霧状の液体を噴霧するとともに、ガスを吹き付けることにより、液体の気化を促進し、気化熱によって表皮の熱を奪い去ることにより表皮を冷却することを特徴とするレーザー照射時の表面冷却方法。



【特許請求の範囲】

【請求項1】レーザー光の照射によって特定の皮下組織を破壊し治療を行う方法において、該皮下組織上の表皮に霧状の液体を噴霧するとともに、ガスを吹き付けることにより、液体の気化を促進し、気化熱によって表皮の熱を奪い去ることにより表皮を冷却することを特徴とするレーザー照射時の表面冷却方法。

【請求項2】上記液体が水又は水とアルコールの混合液であり、上記ガスが圧縮された空気又は窒素ガスである請求項1記載のレーザー照射時の表面冷却方法。

【請求項3】上記霧状液体の噴霧とガスの吹き付けを、レーザー射出部に液体噴霧装置とガスジェットを設置することにより行うことを特徴とする請求項1記載のレーザー照射時の表面冷却方法。

【請求項4】上記液体噴霧装置とガスジェットをレーザーの照射と同期するようにし、レーザー照射の直前に表皮の冷却を行うことを特徴とする請求項1記載のレーザー照射時の表面冷却方法。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】本発明は、レーザー照射時の表面冷却方法に関し、より具体的にはレーザー光の照射によって特定の皮下組織を破壊して治療を行うに際して表皮の冷却を効率的且つ簡便に行うようにしてなるレーザー照射時の表面冷却方法に関する。

【0002】

【従来の技術】レーザー光は医療分野において外科用メスや癌への応用などに適用されてきている。レーザー光の照射によって特定の皮下組織を破壊し治療を行う方法において、表皮の損傷を低減するため、表皮を冷却しながらレーザー照射を行う方法が開発されている。現在開発されている冷却方法には冷温ガスを直接吹き付ける方法と冷水により冷却された固体を皮膚に接触させて冷却する方法がある。冷却された固体は、レーザー光が透過できるようにガラス・石英等の光学材料で構成されている。

【0003】ところが、冷温ガスを直接吹き付ける方法では、冷温ガスを生成させるための冷却装置が必要であるのに加え、冷温ガスの熱容量が小さいため、十分な冷却効果を得るためには多量の冷温ガスを吹き付ける必要がある。また、冷水により冷却された固体を皮膚に接触させて冷却する方法では、別途冷水により固体を冷却するための機構が必要であるばかりか、レーザー光をガラスや石英等の光学材料に透過させる必要があるため、レーザー光にロスが生じる等の問題がある。

【0004】

【発明が解決しようとする課題】本発明は、レーザー光の照射によって特定の皮下組織を破壊し治療を行う方法における、上記のような欠点を解決するためになされたものであり、表皮表面に液体を噴霧してその気化熱によ

り表皮の熱を奪い去ることにより、効率的で且つ簡便なレーザー照射時の表面冷却方法を提供することを目的とする。

【0005】

【課題を解決するための手段】すなわち本発明は、レーザー光の照射によって特定の皮下組織を破壊し治療を行う方法において、該皮下組織上の表皮に霧状の液体を噴霧するとともに、ガスを吹き付けることにより、液体の気化を促進し、気化熱によって表皮の熱を奪い去ることにより表皮を冷却することを特徴とするレーザー照射時の表面冷却方法を提供する。

【0006】

【発明の実施の形態】本発明においては、レーザー光を照射する必要がある表皮面に液体を霧状に噴霧するとともに、ガスを吹き付けることにより、該液体の気化を促進し、その気化熱によって表皮の熱を奪い去ることにより冷却する。使用液体としては、ガスを吹き付けることにより気化する液体であれば特に限定はないが、好ましくは水又は水とアルコールとの混合液が用いられる。また、吹き付け用のガスとしては空気や窒素ガス等適宜のガスが使用される。

【0007】液体の噴霧装置とガスの吹き付け装置（ガスジェット、ガスジェットノズル）はレーザー射出部に一体化して配置するのが好ましい。レーザー光は凸レンズを通して集光され生体中破壊が必要な皮下組織すなわち熱損傷部に照射されるが、液体噴霧装置とガスジェットはレーザー射出部を囲って配置するのが望ましい。

【0008】この場合、ガスは圧縮状態（加圧状態）で供給される必要があるが、圧縮ガスは例えば高压ガスボンベからのガスを用いることで供給することができる。また液体はタンクから導管を通して噴霧装置に供給するが、圧縮ガスによるガスジェットの吸引作用により供給することができる。すなわちその操作時に1種のエジェクター作用を利用する。その際、液体供給用のポンプを併用して供給してもよいことは勿論である。

【0009】図1は本発明で使用し得る装置態様例の概略図である。図示のとおり、レーザー光は凸レンズで集光され、生体中の患部等、すなわち損傷することが必要な皮下組織部分（熱損傷部）に照射される。レンズを経た後表皮に至るまでがレーザー射出部に相当するが、該射出部を順次円筒状に囲んで、ガス供給円管及び液体供給円管が形成されている。液体供給円管を内側に、ガス供給円管を外側に配置してもよい。

【0010】高压ガスボンベ中のガスは導管、弁を介して射出部を囲むガス用円管に供給され、その下端部から噴射される。その際、液体タンク中の液体、例えば水は圧縮噴射ガスの吸引作用により液体導管を経て吸引されて、ガス用円管を囲む液体用円管に導入され、噴射部から噴霧される。ガス供給部及び液体供給部の先端によって噴霧部すなわちノズルが形成され、レーザー照射時、

またはその直前に霧状の液体を表皮に噴霧するとともに、ガスを吹き付ける。これにより、液体の気化を促進し、気化熱として表皮の熱を奪い去ることができる。

【0011】表皮は予め冷却しておくのが望ましい。このため霧状の液体の噴霧とガスを吹き付け時期は、レーザー照射直前であるのがよいが、このため液体噴霧装置とガスジェット(ガスジェットノズル)をレーザーの照射と連動・同期するようにし、レーザー照射の直前に液体噴霧装置からの液体噴霧とガスジェットからのガス吹き付けをレーザー照射の直前に行うようにするのが望まし

い。

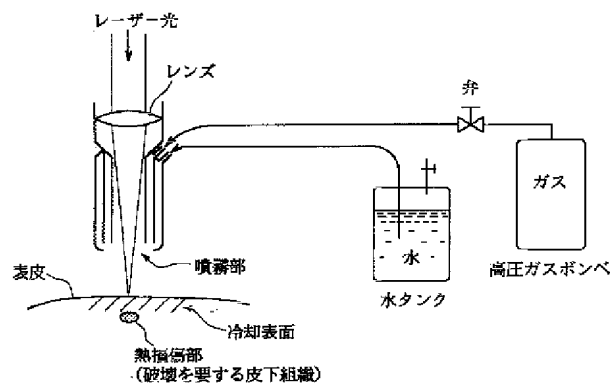
【0012】

【発明の効果】本発明によれば、レーザー光の照射によって特定の皮下組織を破壊し治療を行う方法において、霧状の液体を表皮に噴霧するとともに、ガスを吹き付けることにより、液体の気化を促進し、その気化熱によって表皮の熱を奪い去ることにより表皮を効果的且つ簡便に冷却することができる。

【図面の簡単な説明】

【図1】本発明で使用し得る装置態様例の概略図。

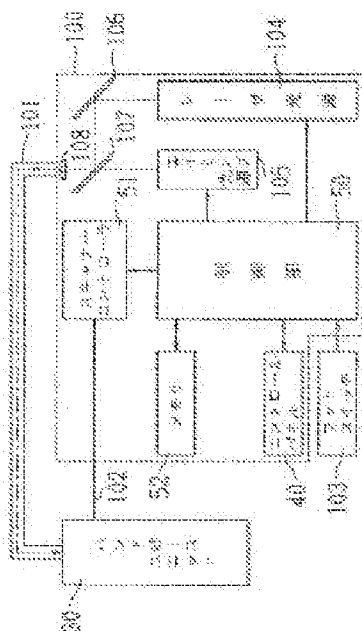
【図1】



LASER THERAPEUTIC EQUIPMENT**Publication number:** JP2000300684 (A)**Publication date:** 2000-10-31**Inventor(s):** MUKAI HIDEO**Applicant(s):** NIDEK KK**Classification:**- **international:** **A61B18/20; A61N5/06; A61B18/20; A61N5/06;** (IPC1-7): A61N5/06; A61B18/20- **European:****Application number:** JP19990112883 19990420**Priority number(s):** JP19990112883 19990420**Abstract of JP 2000300684 (A)**

PROBLEM TO BE SOLVED: To reduce heat damage to a skin caused by the continuous radiation of laser beams by providing a control means for controlling a scanning means to radiate a laser according to the irradiation order of respective spot position determined by an order determining means.

SOLUTION: The order of spots for laser irradiation is previously stored in a memory 52 corresponding to the pattern of scanning shape and size and a scanner controller 51 reads a corresponding pattern from the set scanning shape out of the memory 52 through a control part 50 and controls driving of respective driving motors based on this information. In this case, the arrangement of regular order can be determined by arithmetic processing due to the control part 50 or the like based on the distribution information of spot positions found from the scanning shape and size as well. Therefore, the adjacent beam spot positions or scanning lines are not continuously irradiated and sufficient cooling time can be applied to one irradiated spot.

Data supplied from the **esp@cenet** database — Worldwide

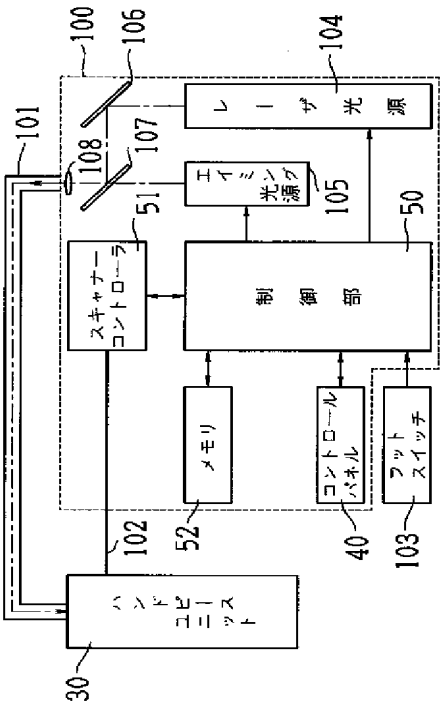
(51)Int.Cl. ⁷	識別記号	F I	テーマコード* (参考)
A 6 1 N 5/06		A 6 1 N 5/06	E 4 C 0 2 6
A 6 1 B 18/20		A 6 1 B 17/36	3 5 0 4 C 0 8 2

審査請求 未請求 請求項の数8 O L （全 7 頁）

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		Fターム(参考)	4C026 AA01 AA03 BB08 FF22 FF23 FF33 FF34 HH02 HH06 HH12 HH16 HH17 HH24 HH30 4C082 RA01 RA05 RC09 RE22 RE23 RE33 RE35 RL02 RL06 RL12 RL16 RL17 RL24 RL30

(54) 【発明の名称】 レーザ治療装置

(57) 【要約】
【課題】 レーザ光の連続照射による皮膚への熱ダメージを軽減することができる装置を提供する。
【解決手段】 治療レーザ光源からのレーザ光をスポット状に形成して患部に導光照射するための導光光学系と、導光光学系に配置され患部領域にスポット照射される前記レーザ光のスポット位置を走査するための走査手段と、走査手段によるスポット位置の走査が連続して隣り合わないよう各スポット位置の照射順序を定める順序決定手段と、順序決定手段により定められた各スポット位置の照射順序に従ってレーザ照射が行われるように走査手段を制御する制御手段とを備える。



【特許請求の範囲】

【請求項1】 治療レーザー光源からのレーザー光をスポット状に形成して患部に導光照射するための導光光学系と、該導光光学系に配置され患部領域にスポット照射される前記レーザー光のスポット位置を走査するための走査手段と、前記走査手段によるスポット位置の走査が連続して隣り合わないよう各スポット位置の照射順序を定める順序決定手段と、該順序決定手段により定められた各スポット位置の照射順序に従ってレーザー照射が行われるように前記走査手段を制御する制御手段と、を備えることを特徴とするレーザー治療装置。

【請求項2】 請求項1のスポット位置とは、前記走査手段によるレーザー光の照射位置の走査を停止させることによりレーザー光がスポット照射される位置であることを特徴とするレーザー治療装置。

【請求項3】 請求項1のレーザー治療装置において、レーザー光の照射領域を可変設定する領域設定手段を備え、前記順序決定手段は設定された照射領域に応じて定められるレーザー光のスポット位置の分布に基づいて各スポット位置の走査が連続して隣り合わないような規則的な照射順序を定めることを特徴とするレーザー治療装置。

【請求項4】 請求項3のレーザー治療装置において、前記領域設定手段により1つのライン上でスポット位置を走査させるように設定された場合には、前記順序決定手段は1ライン上でのスポット位置を少なくとも1つ飛びに順次走査させるよう照射順序を定めることを特徴とするレーザー治療装置。

【請求項5】 請求項4のレーザー治療装置において、前記順序決定手段は1ライン上のスポット位置の数に応じて初期照射のスポット位置を定めることを特徴とするレーザー治療装置。

【請求項6】 請求項3のレーザー治療装置において、前記領域設定手段により複数のライン上でスポット位置を走査させるように設定された場合には、前記順序決定手段は1つのライン上でのスポット位置を所定数の間隔おきに順次走査させた後に次のライン上へスポット位置を移すように照射順序を定めることを特徴とするレーザー治療装置。

【請求項7】 請求項1のレーザー治療装置において、レーザー光の照射領域の形状パターンとそのサイズを設定する領域設定手段と、レーザー照射の形状パターンとそのサイズに応じて各スポット位置の走査が連続して隣り合わないような規則的な照射順序が定められた照射順序パターンを複数個記憶する記憶手段と、を備え、前記順序決定手段は前記領域設定手段による形状パターンとそのサイズの設定に基づいて前記記憶手段の中から照射順序パターンを決定することを特徴とするレーザー治療装置。

【請求項8】 請求項1の走査手段は、レーザー光を反射する2枚のミラーと、各ミラーを揺動させるための揺動手段とを備え、該揺動手段による2枚のミラーを個別に

揺動することにより患部領域上でレーザー光のスポット位置を2次元的に走査するレーザー走査手段であることを特徴とするレーザー治療装置。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】本発明は、治療部位に治療レーザー光を照射して治療を行うレーザー治療装置に関する。

【0002】

【従来技術】従来より、皮膚にレーザー光を照射して、脱毛、皺取り、痣取り等を行うレーザー治療装置が知られている。例えば、レーザー脱毛治療は毛根周辺にレーザー光を照射することにより、その熱エネルギーが毛根部に放熱されて毛根が焼灼されることにより脱毛が行われるものであるが、レーザー光の照射を1パルスずつ行なうような脱毛の治療方法は時間が掛かってしまい効率が悪い。そのため、一度に照射する領域を予め設定しておき、2枚の駆動ミラー等を使用することによってその照射領域にレーザー光のビームスポット（スポット位置）を並べるように走査（スキヤニング）していき、設定した照射範囲全体をもれなく照射して効率よく脱毛が行われるようにしている。

【0003】

【発明が解決しようとする課題】しかしながら、従来のビームスポットの走査は、図5に示すように、照射領域の1ライン目の端から順番に隣へ走査し、これを順次2ライン目、3ライン目と繰り返していくように定められていた。このようなビームスポットの走査の順番であると、最初に照射された時のビームスポットにおける熱緩和時間（レーザー光をターゲットに照射した時、ターゲット周囲の温度分布はその直径で決まる幅を持つガウシアン分布となるが、その分布の中心温度が50%に下がるまでの時間）の影響が考慮されずに隣りのスポット位置に次のビームが照射されてしまうため、皮膚への熱ダメージ（サーマルダメージ）が起こり易いという問題があった。

【0004】本発明は、上記従来装置の欠点に鑑み、レーザー光の連続照射による皮膚への熱ダメージを軽減することができる装置を提供することを技術課題とする。

【0005】

【課題を解決するための手段】上記課題を解決するために、本発明は以下のような構成を備えることを特徴とする。

【0006】（1） 治療レーザー光源からのレーザー光をスポット状に形成して患部に導光照射するための導光光学系と、該導光光学系に配置され患部領域にスポット照射される前記レーザー光のスポット位置を走査するための走査手段と、前記走査手段によるスポット位置の走査が連続して隣り合わないよう各スポット位置の照射順序を定める順序決定手段と、該順序決定手段により定められた各スポット位置の照射順序に従ってレーザー照射が行

われるように前記走査手段を制御する制御手段と、を備えることを特徴とする。

【0007】(2) (1)のスポット位置とは、前記走査手段によるレーザ光の照射位置の走査を停止させることによりレーザ光がスポット照射される位置であることを特徴とする。

【0008】(3) (1)のレーザ治療装置において、レーザ光の照射領域を可変設定する領域設定手段を備え、前記順序決定手段は設定された照射領域に応じて定められるレーザ光のスポット位置の分布に基づいて各スポット位置の走査が連続して隣り合わないような規則的な照射順序を定めることを特徴とする。

【0009】(4) (3)のレーザ治療装置において、前記領域設定手段により1つのライン上でスポット位置を走査させるように設定された場合には、前記順序決定手段は1ライン上でのスポット位置を少なくとも1つ飛びに順次走査させるよう照射順序を定めることを特徴とする。

【0010】(5) (4)のレーザ治療装置において、前記順序決定手段は1ライン上のスポット位置の数に応じて初期照射のスポット位置を定めることを特徴とする。

【0011】(6) (3)のレーザ治療装置において、前記領域設定手段により複数のライン上でスポット位置を走査させるように設定された場合には、前記順序決定手段は1つのライン上でのスポット位置を所定数の間隔おきに順次走査させた後に次のライン上へスポット位置を移すように照射順序を定めることを特徴とする。

【0012】(7) (1)のレーザ治療装置において、レーザ光の照射領域の形状パターンとそのサイズを設定する領域設定手段と、レーザ照射の形状パターンとそのサイズに応じて各スポット位置の走査が連続して隣り合わないような規則的な照射順序が定められた照射順序パターンを複数個記憶する記憶手段と、を備え、前記順序決定手段は前記領域設定手段による形状パターンとそのサイズの設定に基づいて前記記憶手段の中から照射順序パターンを決定することを特徴とする。

【0013】(8) (1)の走査手段は、レーザ光を反射する2枚のミラーと、各ミラーを揺動させるための揺動手段とを備え、該揺動手段による2枚のミラーを個別に揺動することにより患部領域上でレーザ光のスポット位置を2次元的に走査するレーザ走査手段であることを特徴とする。

【0014】

【発明の実施の形態】本発明の形態を図面に基づいて説明する。図1は実施の形態である脱毛用のレーザ治療装置の外観略図を示す。

【0015】100はレーザ装置本体であり、装置本体100内部には後述する制御部50、脱毛用レーザ光源104、エイミング光源105等が収納されている(図

4参照)。レーザ光源104は本形態では連続波(CW)を射出する半導体レーザ(波長835nm)を使用している。また、エイミング光源105は半導体レーザ(波長600nm)を使用している。

【0016】40は照射サイズ、照射密度等のレーザ照射条件等の各種設定条件を入力するためのコントロールパネルである(詳しくは後述する)。101は装置本体1から射出されるレーザ光を導光するための光ファイバー、30はレーザ照射口を持つハンドピースユニットである。102はハンドピースユニット103内部に設置してあるレーザ走査用のミラー32a、32b(図2参照)を駆動させるための電気信号を送るケーブル、103はレーザ光を照射するためのトリガ信号を発信するためのフットスイッチである。

【0017】図2はハンドピースユニット30の概略構成を示す図である。ハンドピースユニット30内には、光ファイバ101内を通過してきたレーザ光を集光するレンズ31a、レンズ31bと、レーザ光を治療部位でXY方向にスキャンさせるための駆動ミラー32a、32bと、各ミラー32a、32bを揺動する駆動モータ33a、33bを備える。レーザ装置本体100からのレーザ光は光ファイバ101を介してハンドピースユニット30に導かれ、光ファイバ101を射出したレーザ光はレンズ31a、レンズ31により照射部位上で直径4mm程度のスポット状に形成されて患部に導光される。

【0018】駆動モータ33a、33bは装置本体100内に設けられたスキャナーコントローラ51により制御される(図4参照)。スキャナコントローラ51は制御信号をケーブル102を介してハンドピースユニット30に送信し、駆動モータ33a及び駆動モータ33bの回転をそれぞれ駆動制御することにより、駆動ミラー32a及び駆動ミラー32bを揺動し、レーザビームの照射のスポット位置を走査させる(走査させる)。なお、34は皮膚に当接させハンドピースユニット30を安定させるとともにレーザ光の集光距離を一定にさせるための位置決めガイドである。

【0019】図3はコントロールパネル40の構成を示した図である。41はモード選択スイッチであり、スキャンニングによるレーザ照射(SCAN)、またはスキャンニングせずに1点照射(BEAM)のモードを選択することができる。42はレーザ照射のスキャンニング形状を選択するための照射形状スイッチであり、スイッチの切替により正方形、長方形、直線、六角形の4種類から選ぶことができる。43は照射形状スイッチ42で選択した照射形状の大きさを変更するための照射サイズスイッチである。照射形状のサイズはそれぞれの照射形状に対して数種類のサイズパターンが予め記憶されている。

【0020】44は照射するビームスポット同士の重なり具合(以下、照射密度と記す)を設定するための照射

密度スイッチである。照射密度スイッチ44により照射密度を、隣どうしのビームスポットが全く重ならず隣接させる照射密度となる0%をはじめ、5、10、15、20、25、30%の7種類から選択できる。45は1照射時間を10～100msecの間にて5msecステップで変更設定するための照射時間設定スイッチである。46は1回のスキヤニングにてレーザー光をOFFするかどうかの設定を行なうシングル設定スイッチである。47は設定されたレーザー照射条件を表示するモニタである。

【0021】次に、以上のような構成を備えるレーザー治療装置において、その動作について図4の制御系及び光学系（レーザー装置本体100側のみ示している）の要部図に基づき説明する。

【0022】電源を投入するとレーザー治療装置はセルフチェックを開始する。スキヤニングによるレーザー照射を行う場合は、セルフチェックの完了後に術者はモード選択スイッチ41を使用してスキヤニングのモードにする。次に、ハンドピースユニット30からの治療用レーザー光が患者の治療部位（脱毛部位）に当たるように位置決めガイド34を治療部付近に当接させる。

【0023】ハンドピースユニット30からはエイミング光源105によるエイミング光が照射されるので、術者はエイミング光の照射位置を確認しながら照射形状スイッチ42、照射サイズスイッチ43、照射密度スイッチ44等を使用し、レーザー光照射条件を設定する。

【0024】設定されたレーザー光照射条件の信号は制御部50を介してスキヤナーコントローラ51に送られる。スキヤナーコントローラ51は設定されたレーザー光照射条件にしたがって制御信号を送信し、駆動モータ33a、33bを駆動させ、駆動ミラー32a、32bを揺動させる。このときエイミング光は前述した駆動ミラー32a、32bの揺動により、設定された照射形状及び照射サイズに基づいて、その輪郭形状を走査するように照射される。

【0025】術者はレーザー光照射条件の設定とエイミング光の観察による照射部位の特定ができた後フットスイッチ103を踏み込むことによりトリガ信号を発信させる。制御部50は、レーザー光源104から治療用レーザー光を出射させる。レーザー光源104を出射した治療用レーザー光は、ミラー106、ダイクロイックミラー107によって反射された後、エイミング光と同軸にされる。エイミング光と同軸にされた後、集光レンズ108によって光ファイバ101に集光、入射される。光ファイバ101に入射された治療用レーザー光（及びエイミング光）はハンドピースユニット30に導光される。

【0026】また、フットスイッチ103からのトリガ信号は制御部40を介してスキヤナーコントローラ51に入力されており、スキヤナーコントローラ51は設定されたレーザー光照射条件にしたがって制御信号を送信し、駆動モータ33a、33bを駆動させ、駆動ミラー

32a、32bを揺動させる。この駆動ミラー32a、32bの揺動により、ハンドピースユニット30に導光された治療レーザー用レーザー光は設定した照射形状及び照射サイズに基づいてスキヤニングされ、患部に照射される。

【0027】次に、本形態のスキヤニング制御によるレーザー照射のスポット位置の順序について、図6～図9を用いて各スキヤニング形状毎（照射領域の形状毎）にそれぞれ説明する。

【0028】まず、本形態によるスキヤニング制御の説明に先立ち、従来のレーザー治療装置における治療用（脱毛用）レーザー光のスキヤニング方法を図5により説明する。図5はスキヤニング形状が正方形で4（ビームスポット）×4（ライン）の場合のスキヤニング方法を示した図である。図において、丸印はレーザー光が照射されるビームスポット位置を、丸印内の数字はスキヤニングの順番を表している。また、照射密度は隣どうしのビームスポットが重ならない0%としている。なお、本実施の形態のレーザー光源は連続波（CW）を出射する半導体レーザーであるため、パルス発振のレーザーと違って駆動ミラー32a、32bが駆動している間もレーザー照射がされているが、移動に要している時間は非常に微小であるため、ここでは駆動ミラー32a、32bが止まった時に照射されるビームスポット位置のみ表示している。

【0029】従来のレーザー治療装置は図5のように照射する順番を横一列ずつ順番に走査していくため、熱による皮膚へのダメージが大きくなる。具体的には、初めの照射地点（数字の1番の位置）からすぐ隣の地点（数字の2番の位置）に続けて照射すると、初めの照射地点に与えられた熱の一部がその周囲に拡散している間に、すぐ隣の照射地点にレーザー光が照射されるため、初めの照射地点から拡散してきた熱量に対して、さらに新たな熱量が加わることとなる。その結果、その地点（ここでは数字の2番の位置）に加わる熱量は、予め設定した熱量よりも高い熱量を持つこととなるため、その地点における皮膚へのサーマルダメージが起り易くなる。

【0030】図6は本発明に基づいてスキヤニングを行なったときの図である。図6（a）はスキヤニング形状が正方形で4（ビームスポット）×4（ライン）の場合、図6（b）はスキヤニング形状が正方形で5（ビームスポット）×6（ライン）の場合を示している。

【0031】先ず、1ラインの左端のビームスポット位置（スポット位置）から照射を開始する。次の位置は、隣のビームスポット位置ではなく、図のように一つおきに照射を行なう。一つのラインに対して一つおきに照射ができなくなると、次に隣りのライン（2ライン）ではなく、一つ間をあけたライン（3ライン）から照射をするようにする。このときも1ラインと同じように左端から照射を始め、同一ライン上で隣り合うビームスポット位置に照射しないように照射していく。このように最初

に奇数ラインから照射を行ない、さらに同一ライン上では左端から一つおきに照射を初めていき、設定された照射範囲内においてすべての奇数ラインが一つおきに照射されると、今度は2ラインにもどり、同じように偶数ラインも左端から一つおきに照射を行う。

【0032】すべての偶数ラインが一つおきに照射されると、また最初に照射をした奇数ライン（1ライン）に戻り、残っているビームスポット位置を同じように奇数ラインから偶数ラインへと照射して、設定された照射領域上のすべてのビームスポット位置への照射を完了させる。

【0033】この他にも6×7、7×8、8×9のパターンが記憶されているが、数が増えているだけで、何れも同じ要領のスキヤニング方法となっている。

【0034】図7は照射形状が直線するとき（4×1、5×1、6×1のパターン）のスキヤニング方法を示している。照射領域形状が正方形のときと同じように、隣り合うビームスポット位置を避けて1つおきに照射を行なっていく。しかしながら、初めの照射地点は左端のビームスポット位置ではなく、その隣のビームスポット位置から始める。仮に左端のビームスポット位置から照射を始めてしまった場合、例えば4×1のパターン（図7（a））では2番目と3番目の照射地点が隣り合ってしまうからである。また、この他にも6×1、7×1、8×1のパターンがあるが、何れも同じようなスキヤニング方法となっている。

【0035】図8は照射形状が長方形（4×2、6×3のパターン）のスキヤニング方法を示している。これも前述したように隣り合うビームスポット位置を避けて、1つおきに照射を行なっていく。図8（a）のように4×2ラインしかない場合、両ラインとも左端からスキヤニングを始めてしまうと、4番目と5番目の照射地点が隣り合ってしまうため、図示のような順序にてスキヤニングを行なう。

【0036】図9は照射形状が六角形（4×3、6×5のパターン）のスキヤニング方法を示している。これも前述したように1つおきに照射を行なっていく。図9（a）の場合、3ラインとも左端から照射を開始してしまうと、6番目と7番目の照射地点が隣り合ってしまうため、図示のような順序にてスキヤニングを行なう。また、この他にも7×7のパターンがあるが、同じスキヤニング方法となっている。

【0037】こうしたレーザ照射のスポットの順序は、スキヤニング形状とその大きさのパターンに応じて予めメモリ52に記憶されており、スキャンコントロール51は設定されたスキヤニング形状から対応するパターンを制御部50を通じてメモリ52から呼び出し、この情報に基づいて各駆動モータ33a、33bを駆動制御する。なお、隣り合うところが無いように定められたスポット位置の順番は、パターンに応じて予め定めたものを

メモリ52に記憶しておく他、スキヤニング形状とその大きさ（さらに照射密度の設定情報）から求められるスポット位置の分布情報に基づき、こうした規則的な順番の配置を制御部50等が演算処理して定めるようにしても良い。

【0038】このように、隣り合うビームスポット位置、スキヤニングラインを連続して照射をすることがないため、一つの照射地点（ビームスポット位置）に対して十分な冷却時間を与えることができる。その結果、脱毛に必要な熱量は確保すると同時に余計な熱を加えることがないため、皮膚へのサーマルダメージが抑制できる。

【0039】以上、本実施の形態では半導体レーザを使用しているが、これに限るものではなく、レーザの種類、発振方法（連続波、パルス等）によらず使用することが可能である。

【0040】また、スキヤニング方法も全ての領域で隣り合うビームスポット位置を連続して照射しないように制御することができればこれに限るものではなく、例えば最初の照射地点を左端からではなく、右端からとしたり、奇数ラインからではなく偶数ラインから照射を行うことも可能である。

【0041】

【発明の効果】以上説明したように、本発明によれば、隣り合うスポット位置に連続してレーザ光を照射することがないため、十分な熱緩和時間を維持し、皮膚への過剰な熱供給を抑えてサーマルダメージを抑制することができる。

【図面の簡単な説明】

【図1】装置の外観図である。

【図2】ハンドピースユニットの詳細を示す図である。

【図3】コントロールパネルの詳細を示す図である。

【図4】制御系及び光学系を示す要部図である。

【図5】従来のスキヤニング方法を示す図である。

【図6】本発明における照射形状が正方形の場合のスキヤニング方法を示す図である。

【図7】本発明における照射形状が直線の場合のスキヤニング方法を示す図である。

【図8】本発明における照射形状が長方形の場合のスキヤニング方法を示す図である。

【図9】本発明における照射形状が六角形の場合のスキヤニング方法を示す図である。

【符号の説明】

30 ハンドピースユニット

40 コントロールパネル

50 制御部

51 スキャナーコントローラ

52 メモリ

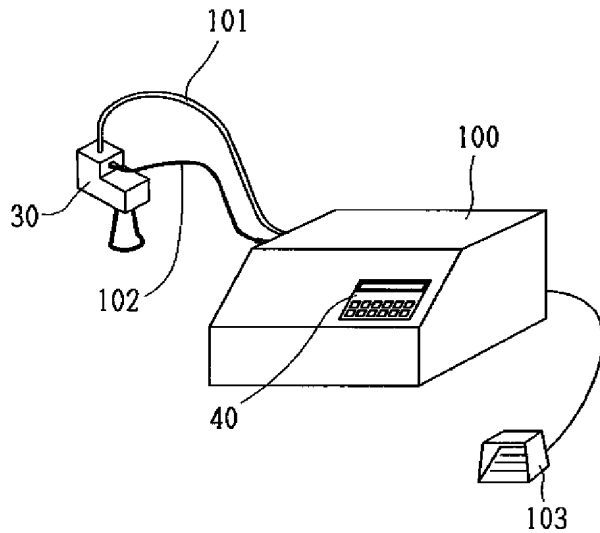
100 レーザ装置本体

101 光ファイバ

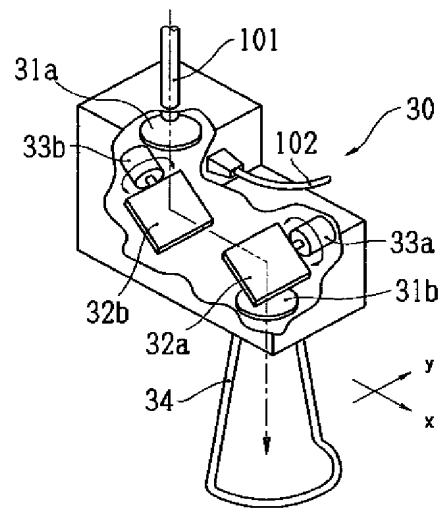
102 ケーブル
103 フットスイッチ

104 レーザ光源
105 エイミング光源

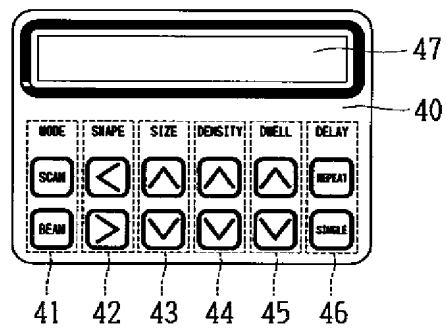
【図1】



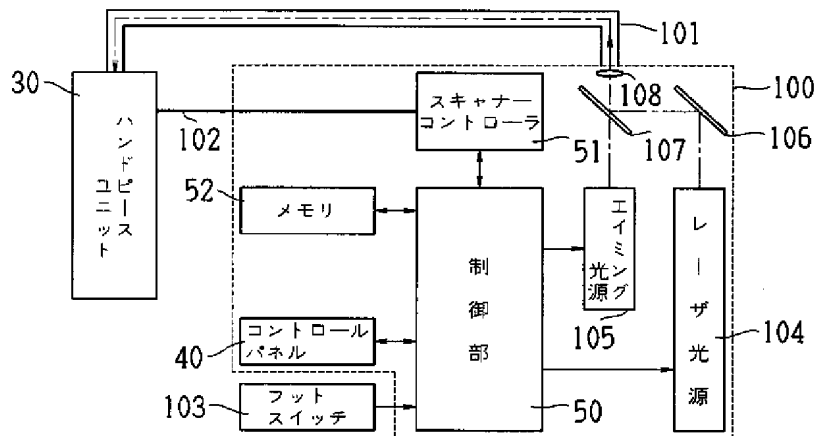
【図2】



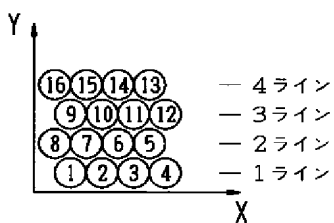
【図3】



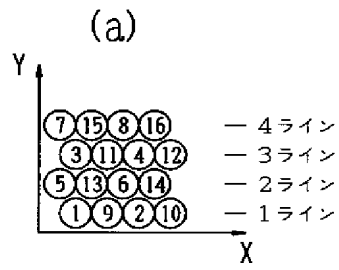
【図4】



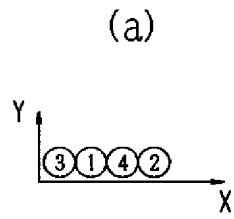
【図5】



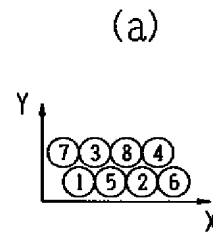
【図6】



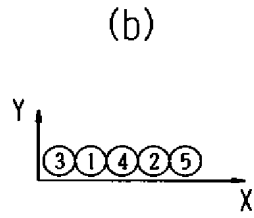
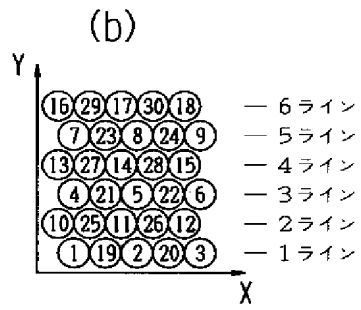
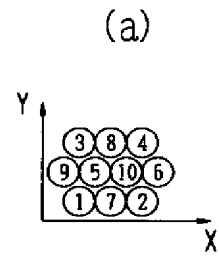
【図7】



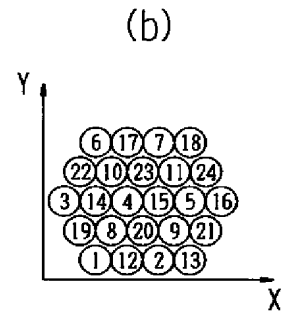
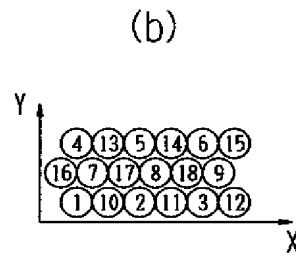
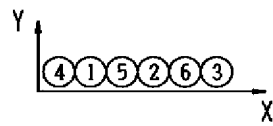
【図8】




【図9】



(c)

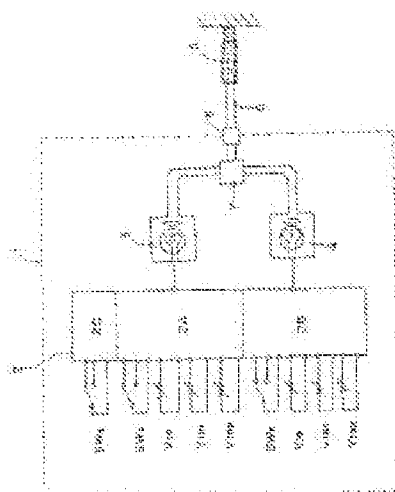


OPTICAL DEPILATING DEVICE**Publication number:** JP3066387 (A)**Publication date:** 1991-03-22**Inventor(s):** YAMAZAKI IWAO**Applicant(s):** YA MAN LTD**Classification:**- **international:** **A61N5/06; A45D26/00; A61N5/06; A45D26/00;** (IPC1-7): A61N5/06- **European:****Application number:** JP19890200296 19890803**Priority number(s):** JP19890200296 19890803**Also published as:** JP2854027 (B2)**Abstract of JP 3066387 (A)**

PURPOSE: To automatize the start of irradiation and to reduce the fatigue at the time of irradiation by providing a means for executing alternately the irradiation and the stop of an irradiation probe, and varying independently an interval of an irradiation period and a stop period on an electric control part.

CONSTITUTION: At the time of executing the optical depilation, a use condition of a light emission source of each color, that is, changeover switches SWR, SWB, strength setting parts VIR, VIB, irradiation period setting parts VTR1, VTB1, and stop period setting parts VTR1, VTB1 are set. In the case of radiating a red light, a red color irradiation probe 5 is installed in a photoconductor cable connector 8, and the selection of a use light source is switched to a contact position R by a switch SWS. Also, in the case of a blue color, the switch SWS is switched to a contact position B. A red color or blue color light emission source always execute a light emission and a stop in accordance with the sequence.

Therefore, a user moves the irradiation probe to a desired part of the skin in the course of a stop period, and executes the radiation during the irradiation period for pressing and fixing it. Since the start of irradiation is determined automatically in the device, fatigue is not generated against use of many hours.



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平3-66387

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識別記号

庁内整理番号

⑬ 公開 平成3年(1991)3月22日

A 61 N 5/06

Z

8117-4C

審査請求 未請求 請求項の数 2 (全7頁)

⑭ 発明の名称 光脱毛装置

⑰ 特 願 平1-200296

⑱ 出 願 平1(1989)8月3日

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㉑ 代 理 人 弁理士 江崎 光好 外1名

明 細 書

1. 発明の名称

光 脱 毛 装 置

2. 特許請求の範囲

1. 赤色発光源及び青色発光源と、上記二つの光源から出射した光を外部に照射する照射プローブと、前記両発光源を電気的に制御する電気制御部とを備えた光脱毛装置において、

電気制御部には照射プローブの照射の実行と休止を交互に連続して行い、照射期間と休止期間の間隔を互いに独立して可変できる手段が装備してあることを特徴とする光脱毛装置。

2. 赤色発光源及び青色発光源と、上記二つの光源から出射した光を外部に照射する照射プローブと、前記両発光源を電気的に制御する電気制御部とを備えた光脱毛装置において、

照射プローブを保持し、横方向の移動を容易にするプローブ・キャリアが具備しており、このプローブ・キャリアには移動距離を検出する検出器が装備しており、電気制御部にはこの検

出器の出力信号から対象物に出射している照射時間を算定して所望照射時間の範囲内にあるかを判定する電気回路が配設してあることを特徴とする光脱毛装置。

3. 発明の詳細な説明

〔産業上の利用分野〕

この発明は、光脱毛装置、より詳しくは光を用いて皮脂腺と毛嚢内の毛の因子を乾固させ、永久脱毛を助長するため自動的に使用できる永久光脱毛装置に関する。

〔従来の技術〕

上に述べた種類に属する光脱毛装置は、特願平1-12459号公報により公知である。この公報に開示された光脱毛装置を利用する場合、照射光の光源としてそれぞれ赤色と青色の可視光領域に主強度を有する二種の発光光源を利用している。最初の予備加熱（プレヒーティング）で、比較的弱い強度の赤色光を脱毛すべき個所全体にまんべんなく照射する。次いで、比較的強い強度の赤色光で前記脱毛個所を照射して、皮脂腺開口部にある

毛の因子を乾固させる。その後、比較的強い青色光を照射して皮脂腺と毛嚢内の毛の因子を乾固させる。この状態にした後、脱毛ワックスにより照射箇所にある毛を脱毛する。その後、脱毛処理後によって開いた毛穴から毛の成長と発育を抑制するために使用する蛋白質分解酵素を擦り込む。この蛋白質分解酵素の働きを更に活性化させるため、比較的弱い赤色光を再び脱毛箇所に照射する（フラッシング）。

上記特願平 1-12459 号公報に開示した装置を使用する際、照射の開始はこの脱毛装置本体外に装備し、本体と電気導線を介して電気接続されているスイッチ、例えば足踏スイッチ又は照射プローブに付属させてあるマイクロスイッチを用いている。周知のように、脱毛したい箇所は、例えば脇の下のような狭い局所的な箇所の場合もあるが、総じて広い面積におよぶ箇所、例えば足の膝から下全部であったり、あるいは背中全体であったりする。照射プローブの照射領域の大きさは、例えばハロゲン・タングステン白熱灯による赤色

の比較的強い照射の場合、直径が約 5 mm φ で、キセノン・ランプによる青色の比較的強い強度の光では約 10 mm φ である。それ故、上に述べた広い面積をこの様に狭い照射範囲を有する照射プローブで処理するには、照射位置を百回またはそれ以上の回数も移動させて照射する必要がある。この困難を低減させるには、光源の強度を上げて照射面積を広くすることも考えられる。しかしながら、この処置では装置自体をいたずらに大型化し、価格の大幅な上昇と保守時の経費が嵩むことになる。それどころか、一回の照射で皮膚に加わる負担が大きく、装置に万一の故障があり、強力な照射光が所定時間よりも長く皮膚に照射されれば、身体に対して非常な危険が加わる恐れがある。

その外、前記特願平 1-12459 号公報で開示した実施例では、照射開始を上記の外部スイッチで行い、照射終了を本体に内蔵したタイマーで自動的に決めている。この方式の場合、上に述べた百回またはそれ以上の回数でこの外部スイッチを操作しながら、照射プローブの移動と位置設定

を行う必要がある。脱毛処理を実際に行う人は、通常専業としている使用者であるが、一日に一人だけでなく、数人又は十数人の人に対して脱毛を行う。それ故、この外部スイッチを操作するのみで既に足又は指先に疲労を覚える。しかも、照射プローブの移動と設定にも、使用者はこのプローブを横に移動させる運動と皮膚に押し付ける運動とが要求されるので筋肉疲労が生じる。このことは、使用回数が増加すると、使用者に疲労が重なり職業病にもなりうることを意味する。

更に、上に試算した百回以上の移動と設定には多から少なかれ何らかの時間を要し、一回の移動に要する時間がたとえ比較的少なくても、これ等の移動全体で積算すると、意外に長時間を要し、実効使用時間を非常に浪費することになる。

〔発明が解決しようとする問題点〕

上に述べた従来の装置に見られる難点を鑑み、この発明の課題は、照射を開始させる操作を手動でなく、自動化して実効使用時間を有効に活用し、同時に照射時に生じる疲労を大幅に軽減する光脱

毛装置を提供することにある。

〔問題点を解決するための手段〕

上記の課題は、この発明により、赤色発光源及び青色発光源と、上記二つの光源から出射した光を外部に照射する照射プローブと、前記両発光源を電氣的に制御する電気制御部とを備えた光脱毛装置であって、電気制御部には照射プローブの照射の実行と休止を交互に連続して行い、照射期間と休止期間の間隔を互いに独立して可変できる手段が装備してある光脱毛装置、又は赤色発光源及び青色発光源と、上記二つの光源から出射した光を外部に照射する照射プローブと、前記両発光源を電氣的に制御する電気制御部とを備えた光脱毛装置であって、照射プローブを保持し、横方向の移動を容易にするプローブ・キャリアが具備してあり、このプローブ・キャリアには移動距離を検出する検出器が装備してあり、電気制御部にはこの検出器の出力信号から対象物に出射している照射時間を算定して所望照射時間の範囲内にあるかを判定する電気回路が配設してあることを特

微とする光脱毛装置によって解決されている。

〔作 用〕

上記の構成により下記の作用が得られる。即ち、いずれの光の照射開始も装置内で自動的に決定される。また、照射プローブを皮膚に押し付けて移動させることができる。そして移動速度に見合った照射が自動的に行われ、同一箇所を許容時間以上照明することがない。

〔実施例〕

この発明による光脱毛装置の実施例を以下に図面に基づき詳しく説明する。

第 1 図には、この発明による光脱毛装置の機能ブロック図が示してある。既に特願平 1-12459 号公報で開示したように、照射プローブと発光光源との間に使用する連結部には種々の方式がある。説明の理解を助けるため、照射プローブ 5 は一個で、連結部 6 も一本で、赤色発光光源 3 と青色発光光源 4 から発する各光は、本体 1 内部に配設してある混合器 7 を経由して連結部 6 に導入される方式のものを使用する。もちろん、その他

には赤色発光光源 (R) を使用するか、あるいは青色発光光源 (B) を使用するかを選択する切換スイッチ SW_s が装備してある。なお、この発明自体に直接関係のない、例えば主電源開閉器、表示ランプ等のそれ自体公知でどの電気装置にも通常使用される機能部品は説明を複雑にするので図示しない。

この実施例に示す脱毛装置の動作は、第 2 図に示す発光光源 3 又は 4 をトリガーするためのトリガー信号波形から理解できるように、照射プローブ 5 の照射期間が T_A であり、休止期間が T_B であるように設定してある。光照射は両期間 T_A 、 T_B が交互に切り替わるこのトリガー信号によって制御される。このようなスイッチング波形を発生させる回路は、当業者であれば容易に推察できるように、自走マルチバイブレータ (双安定マルチバイブレータ) を用いて極めて容易に構成できる。その外、市販のタイマーないしはシーケンス・コントロール・ユニットでも形成できる。その際、照射期間と休止期間の時定数は、それぞれに対応す

る方式でも以下の説明から容易にこの発明の構成を適用できることは明らかである (詳しくは、特願平 1-12459 号公報参照)。

この発明の第一の実施例では、第 1 図の光脱毛装置の本体 1 中に装備してある発光光源の電気制御部 2 に次の処置が講じてある。つまり、この制御部 2 は三個に分割して、それぞれ赤色発光光源制御部 2 A、青色発光光源制御部 2 B 及び共通制御部 2 C から構成されている。本体 1 中にある操作を設定する主要部は、それぞれ赤色発光光源制御部 2 A に、赤色発光光源を自動 (A) 又は手動 (M) で操作するための切換スイッチ SW_R 、赤色光の強度設定部 V_{IR} 、赤色光の照射を継続する照射期間設定部 V_{TRI} 、赤色光の照射を中断している休止期間設定部 V_{TRB} が、また青色発光光源制御部 2 B に、青色発光光源を自動 (A) 又は手動 (M) で制御するための切換スイッチ SW_B 、青色光の強度設定部 V_{IB} 、青色光の照射を継続する照射期間設定部 V_{TBI} 、青色光の照射を中断している休止期間設定部 V_{TB} が配設してある。更に、共通制御部 2 C

る RC 回路素子によって決まるのもで、第 1 図ではこの回路素子を可変抵抗にして暗示的に示してある (もちろん、この設定は可変抵抗でなく、可変コンデンサで実現できることは言うまでもない)。即ち、赤色を例にとれば、照射期間 T_A は照射期間設定部 V_{TRI} によって、また休止期間 T_B は休止期間設定部 V_{TRB} によって設定される。

上の説明は、赤色発光光源の場合に対して説明したが、同様な設定は青色発光光源の場合に対しても当てはまる。

第 1 図の構成でこの発明による光脱毛を実際に行うには、各色の発光光源の使用条件の設定 (切換スイッチ SW_R 、 SW_B 、強度設定部 V_{IR} 、 V_{IB} 、照射期間設定部 V_{TRI} 、 V_{TBI} 、休止期間設定部 V_{TRB} 、 V_{TB} 等) は既に完了していると仮定すると、赤色光を照射する場合、先ず脱着可能な光導体ケーブル・コネクタ 8 に赤色光照射プローブ 5 を装着して、使用光源の選定をスイッチ SW_s によって接点位置 R に切り換える。また、青色の場合にはスイッチ SW_s を接点位置 B に切り換える。赤色

光のプレヒーティング及びフラッシングでは、光照射強度を低くして照射面積を広げて照射するので照射プローブ 5 の交換、又はプローブ先端にアダプターを付ける必要がある（特願平 1-12459 号公報参照）。赤色又は青色発光源は、常時第 2 図のシーケンスに従って発光、休止を行っている。それ故、使用者は照射プローブと休止期間 T₁ の間中に皮膚の所望箇所に移動させ、その上に押圧固定する照明期間 T₂ の間照射する。

第 2 図の照射条件では、休止期間を出来る限り短くして、照射プローブをこの間隙の照射箇所に移動させて、有効作業時間を短縮する必要がある。それには、照射プローブの移動を絶えず素早く行う訓練が使用者に対して必要である。

この照射プローブの移動と照射期間との関係を使用者の訓練を待たずに実行できる装置の照射プローブ部分を第 3 a 図と第 3 b 図に示す。第 3 a 図の断面図には、第 1 図の照射プローブ 5 に相当する光導体ケーブル 11 の先端部分 16 が、非導電性材料のゴム又はプラスチック製のプローブ・

キャリア 10 の対応する穴に挿入してある。その場合、外部被覆 12 の段が対応するキャリア 10 の表面に当接するまで挿入してある。このキャリア 10 の窪み 18 には、中心を貫通する回転軸 22 を具備するロール 20 がキャリア 10 中に埋め込んである軸受（図示せず）に回転可能に支承されている（第 3 b 図も参照）。このロール 20 の表面近傍に多数の、例えばフェライトあるいはサマリウム・コバルト合金等の永久磁石片 24 が等間隔で埋め込んである。これ等の磁石片 24 は、その着磁方向を交互に逆転させて配列してある。他方、窪み 18 の底の部分には磁場検出用センサ 30 が埋め込んである。このセンサの出力信号は、給電・出力信号線 32 を経由してコネクタソケット 35 のソケットピン 34 を挿入できるリセブタクル片 33 に通じている。出力信号はこのピン 34 から更に導線 36 を経由して本体 1 の信号処理回路 2 に導入される。

プローブ・キャリア 10 は、この断面図から理解できるように、皮膚 38 に密着させたまま移動

できるので、従来の照射プローブのように移動の際皮膚から一旦離して、所望の脱毛箇所に再び押し付ける動作は不要である。そのため、無駄な力を使わずにプローブ先端 16 を移動させることができる。更に、重要なこのキャリア 10 の特徴として、キャリア 10 の動きに伴い回転するロール 20 中の永久磁石片 24 が、磁場検出用センサ 30 に磁場変化を与えるので、出力信号も変化させる。このようにして、ロール 20 の移動距離が検出される。

先に説明した第一実施例では、特に図示しなかったが、照射プローブをここに示したロール付きキャリアに装着し、しかも位置検出部を取り付けておかなくても、その作業上の有用性は上に述べた理由により明らかである。

第 4 図には、この出力信号を利用してプローブ・キャリア 10 の適正な移動速度及び過度の光照射を防止させる照度検出演算部 100 の概要が示してある。

磁場検出用センサ 30 を、例えばホール素子 M

S とする。この素子 MS の両端に基準電位を印加し、直交方向の端部から周知のようにホール電位を測定すると素子 MS の受けている磁場を初段増幅器 A₁ によって知ることができる。得られた出力信号は初段増幅器 A₁ の出力端側に模式的に示した波形であるが、この信号を波形整形回路 T₁ に導入して、正又は負の信号レベル側に飛び出す方形波に整形して正の方形波からトリガーパルスを形成するトリガー段 LMT と、負の方形波からトリガーパルスを形成するトリガー段 INV に導入する。両トリガーパルスは、それぞれフリップ・フロップ FF のセット及びリセット端子 S、R に導入される。フリップ・フロップ FF の出力信号 Q は、計数器 CNT のセット端 S' に導入される。他方、この計数器 CNT には、クロック発生器 CLK のタイミングパルスを分周器 DV で適当な周期のクロックパルスに落として前記計数器 CNT に導入する。計数器 CNT のリセットは、フリップ・フロップの \overline{Q} 出力によって各対の磁極片毎に行われる。

計数器 C N T の計数出力は、隣合った永久磁石片 2 4 がホール素子 M S を通過した時間を表すもので、この磁石間の距離は既知であるから、ロール 2 0 の回転速度も算出できる。従って、この計数出力を更にデジタルウインド比較器 L と U に導入して、ここでロール 2 0 の回転速度が所定の回転速度内、つまり最低許容速度と望ましい最高速度の間にあるか否かを判定できる。最低許容速度と望ましい最高速度に対応するデジタルしきい値は、付属キーボード C B D から入力されて、符号化回路 E N C で符号化処理され、それぞれ信号導線 α と γ を経由して比較器 L と U に導入されている。ロール 2 0 の回転速度が望ましい最高しきい値を越えると、比較器 U の出力 O U T 2 は、例えば「H」レベルに変わり、越えなければ「L」レベルを維持する。他方、ロール 2 0 の回転速度が最低許容しきい値以下であれば、比較器 L の出力は「L」レベルを維持しているが、このしきい値以上では比較器 L の出力は、ロール 2 0 の回転速度が遅すぎると言う警報信号に相当する「H」レ

ベルに変わる。そして、この出力はモノステーブルマルチバイブレータ M S T に導入されて、第 2 図に示した休止時間 T_0 に相当する時間の後、再び「L」レベルに戻る。 T_0 に相当する時間の指定はキーボード C B D から符号化回路 E N C と導線 β を経由してモノステーブルマルチバイブレータ M S T に導入されている。そこから出力 O U T 1 として外部に出力される。

出力 O U T 1 が「H」レベルになることは、照射時間が許容範囲以上に長いことを意味し、照射発光光源を休止させる指令を照度検出演算部 1 0 0 からこの発光光源の駆動回路（例えば、第 1 図の発光光源 3 又は 4）に出力するように設計する。同時に、この状態を本体 1 の表示部の、例えば L E D に表示したり、あるいは音声で警報するのも効果的である。また出力 O U T 2 が「H」レベルであれば、照射時間が短いことを意味し、照射が不十分である。その場合は手動で行っているグローブ・キャリヤ 1 0 の移動速度を遅くする必要がある。もちろん、この状況も表示ランプ及び／又は

音声警報を表示警告すると効果的である。

照射グローブの有効照射面の直径（又は一方の辺の長さ）を D とすると、グローブの移動速度 v は、第 2 図に規定した適正照射期間 T_A に対して次の関係、

$$v = D / T_A$$

を満たす必要がある。この速度は、第二実施例の照射グローブ・キャリヤの適正移動時の移動速度を規定するもので、その速度の上限と下限の二パラメータは第 1 図の照射期間設定部 V_{TR1} , V_{TR2} と休止期間設定部 V_{TR1} , V_{TR2} に相当する。

上記の第二実施例では、ロール 2 0 の回転速度を磁気検知素子で検出しているが、この技術思想を光電的に実現することも可能である。この場合、検出器 3 0 は発光素子として発光ダイオード、受光素子としてフォトランジスタによって構成され、磁石片 2 2 は単に光の反射材料で作製される。更に、照度検出演算部 1 0 0 は、ほぼ類似な回路方式で形成することができる。

その外、ここに示した二つの実施例はこの発明の根底をなす設計思想を逸脱することなく、種々の様式に変形することができるのは明白である。例えば、例えば第 3 a, b 図のロール 2 0 をキャリヤ 1 0 の中に一個だけでなく、二個又はそれ以上配設することもできる。また、デジタル入力方式である第 4 図のキーボード C B D を、第 1 図の照射光強度設定部、照射時間設定部のような可変抵抗のようなアナログ入力方式もそれに応じた照度検出演算部 1 0 0 内の回路を変更すれば可能である。

〔発明の効果〕

この発明による光脱毛装置の著しい利点は、

- (1) 照射開始を外部操作によって行わず、自動的に装置内で決定されるので、長時間の使用に対して疲れが生じない。
- (2) この発明の第二実施例の構成によれば、照射グローブを皮膚から離して移動させるのではなく、常時押し付けて実行できるので、長時間の使用に対して疲れが生じない。

- (3) 移動速度に見合った照射を自動的に保証でき、また同一箇所を許容時間以上照明することがないので、安全に使用できる。
- (4) 休止期間を短縮できる、ないしは休止期間がないので、脱毛処理能力が著しく上昇することにある。

4. 図面の簡単な説明

第1図は、この発明による第一実施例としての光脱毛装置のブロック図である。

第2図は、第1図の光脱毛装置で使用する自動照明駆動シーケンスの出力信号の波形図である。

第3a図と第3b図は、照射プローブと移動速度検出器を装着したプローブ・キャリアの断面図と下から眺めた平面図である。

第4図、第3a、b図のキャリアの移動速度を検出した出力信号の演算処理部を示すブロック回路図である。

図中引用記号：

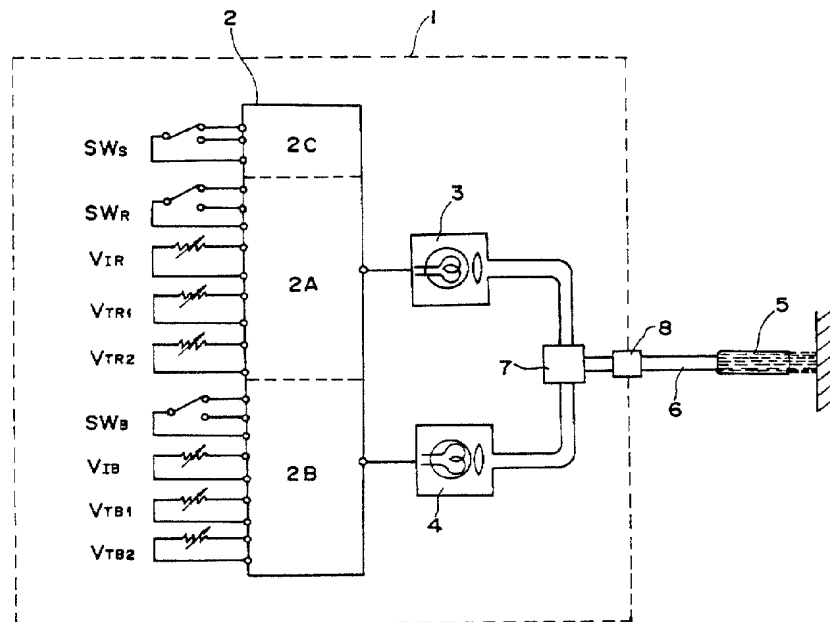
- 1・・・本体、
2・・・電気制御部、

- 3・・・赤色発光源、
4・・・青色発光源、
5・・・プローブ、
10・・・プローブ・キャリア、
20・・・ロール、
24・・・磁石片、
30・・・磁気検出器、
100・・・照度検出演算部。

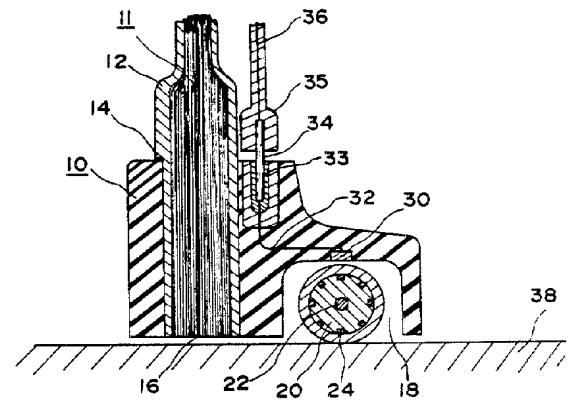
代理人 江崎光好

代理人 江崎光史

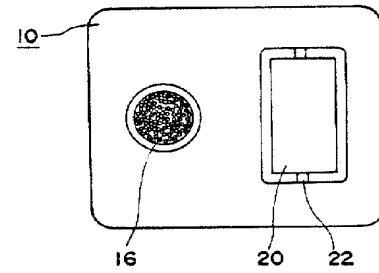
第1図



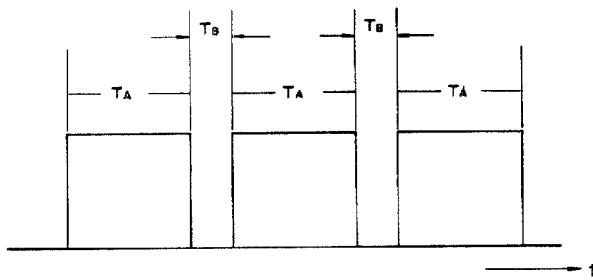
第 3a 図



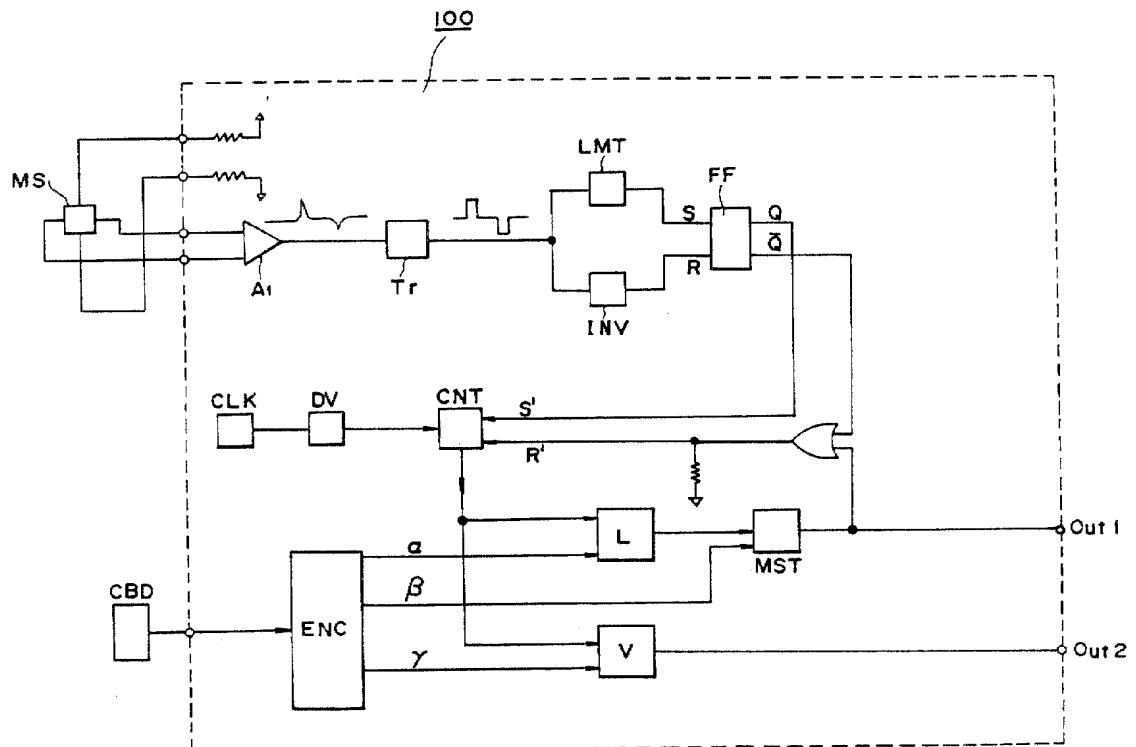
第 3b 図



第 2 図

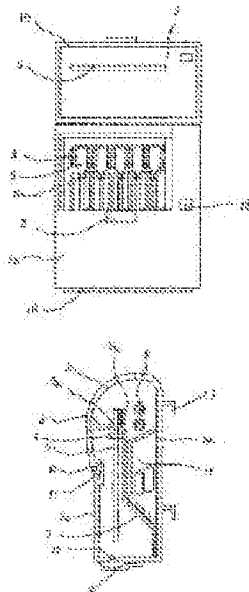


第 4 図



TOOTHBRUSH CASE WITH STERILAMP**Publication number:** JP6022871 (A)**Publication date:** 1994-02-01**Inventor(s):** NIIDA HIDEYO**Applicant(s):** NIIDA HIDEYO**Classification:**- **international:** **A47K1/09; A47K1/00; A47K1/08; A47K1/00;** (IPC1-7): A47K1/09- **European:****Application number:** JP19920200397 19920703**Priority number(s):** JP19920200397 19920703**Abstract of JP 6022871 (A)**

PURPOSE: To completely execute sterilization of a toothbrush by providing a toothbrush position fixing means, and positioning exactly a brush part of the toothbrush in a toothbrush case, in a sterilizing ray radiating part of the sterilamp. **CONSTITUTION:** In a case main body, a toothbrush holder 7 in which plural pieces of sandwiching means 6 for sandwiching a toothbrush 5 by spring elasticity with a neck part 5a of the toothbrush 5 are provided in the horizontal direction is attached so as to be freely attachable and detachable. In such a state, when the toothbrush 5 is contained in a toothbrush case, a brush part 5b of the toothbrush 5 is fixed as to its position so that its bristle tips are turned toward a sterilamp 8, not inclined, and bristles of the brush part 5b are held in parallel or roughly parallel to the radiating direction of a sterilizing ray. That is, by the sandwiching means 6 provided in the toothbrush holder 7, the brush part 5b of the toothbrush is fixed as to its position roughly in parallel to the ultraviolet lamp 8 provided in the inner part of the upper part of the case main body. In such a way, the bristle root part of the brush part 5b in which bacteria propagate themselves most can be irradiated with the sterilizing ray, and sterilization can be executed completely.



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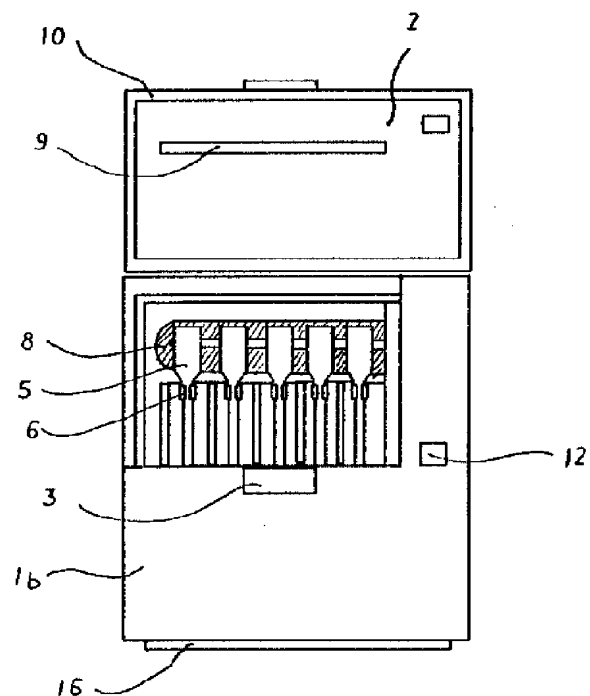
(74) 代理人 弁理士 辻 良子

(54) 【発明の名称】 殺菌灯付き歯ブラシケース

(57) 【要約】

【構成】 歯ブラシのブラシ部を殺菌灯の殺菌光線放射部位に適確に位置させるための歯ブラシ位置固定手段を有する殺菌灯付き歯ブラシケースであり、歯ブラシ位置固定手段は好ましくはバネ弾性を有する挟持手段からなっている。

【効果】 本発明の殺菌灯付き歯ブラシケースは、歯ブラシ位置固定手段を備えているので、歯ブラシのブラシ部の毛先を殺菌灯の方に向けて、傾いたりせずに殺菌灯に対して平行またはほぼ平行に保つように位置固定することができ、それによって菌類の繁殖の一番多いブラシ部の毛根部分にまで殺菌光線を照射することができ、歯ブラシの殺菌を完全に行うことができる。



【特許請求の範囲】

【請求項1】 歯ブラシのブラシ部を殺菌灯の殺菌光線放射部位に適確に位置させるための歯ブラシ位置固定手段を有することを特徴とする殺菌灯付き歯ブラシケース。

【請求項2】 歯ブラシ位置固定手段がバネ弾性を有する挟持手段からなっている請求項1の歯ブラシケース。

【請求項3】 歯ブラシ位置固定手段が歯ブラシの首部に相当する箇所に設けてある請求項1または2の歯ブラシケース。

【発明の詳細な説明】

【0001】

【産業上の利用分野】 本発明は殺菌灯付き歯ブラシケースに関する。詳細には、殺菌灯からの殺菌光線が歯ブラシのブラシ部の毛根部分にまで適確に照射されるようにした殺菌効果の極めて高い殺菌灯付き歯ブラシケースに関する。

【0002】

【従来の技術】 歯ブラシに付着している水分、食べ物の残りかす、歯垢、口内に生息していた雑菌等により歯ブラシのブラシ部には多くの菌類が通常繁殖しており、極めて不衛生であることは従来からも指摘されている。特に最近の歯ブラシは、歯垢除去のためにブラシ部の植毛密度が高くなっていて乾きにくいところから、菌類の繁殖が著しい。

【0003】 そして、歯ブラシを収納する歯ブラシケースでは、ブラシ部に付着していた口臭や菌類の繁殖によって発生した異臭がケース内に充満したり、ゴキブリ等の害虫もケース内に出入りしていることもあり、歯ブラシのブラシ部とともに歯ブラシケースも極めて不衛生な状態となっていることが多い。

【0004】 上記の点から、歯ブラシケース内に殺菌灯を取り付けて歯ブラシのブラシ部、および場合によっては更にケース内の殺菌を行うことが種々提案されている。そして、従来の殺菌灯付き歯ブラシケースでは、ケース内に歯ブラシを収納するに当たって、複数本の歯ブラシを懸垂して保持するための複数の凹部を有する懸垂板を殺菌灯の近くに設けたり（例えば実開昭56-176738号公報、実公昭63-31675号公報等）、歯ブラシを仕切られた個々の歯ブラシ室に立てて挿入する方法が採用されている。

【0005】 歯ブラシでは、ブラシ部の毛根部分が、特に食物滓がたまり易く且つ毛が密集していて奥まで洗浄しにくいために、最も菌類の繁殖が著しく不潔になり易い。しかし、ケース内の懸垂板に設けた凹部に歯ブラシを単に懸垂したり、ケース内の仕切られた個々の歯ブラシ室に歯ブラシを単に立てて挿入するだけの上記した従来の殺菌灯付き歯ブラシケースの場合は、懸垂板に懸垂したり歯ブラシ室に挿入した歯ブラシが傾いたり、横やその他の方向に向いてしまっ

て、毛が殺菌光線の照射方向に向かないことがしばしばある。その結果、殺菌光線が、菌類の最も繁殖し易いブラシ部の毛根部分にまで到達しなくなり、殺菌効果が充分にあげられないという欠点がある。

【0006】

【発明が解決しようとする課題】 したがって、本発明の目的は、ブラシ部の毛根部分にまで殺菌光線が充分にきちん

【0007】

【課題を解決するための手段】 本発明者の長年の研究の結果、本発明者は、歯ブラシケースに、歯ブラシのブラシ部を殺菌灯の殺菌光線放射部位に適確に位置させるための歯ブラシ位置固定手段を設けると、上記の目的を達成できることを見い出して本発明を完成した。

【0008】 したがって、本発明は、歯ブラシのブラシ部を殺菌灯の殺菌光線放射部位に適確に位置させるための歯ブラシ位置固定手段を有することを特徴とする殺菌灯付き歯ブラシケースである。

【0009】 本発明における「歯ブラシのブラシ部を殺菌灯の殺菌光線放射部位に適確に位置させるための歯ブラシ位置固定手段」とは、歯ブラシを歯ブラシケース内に収納した際に、歯ブラシのブラシ部を、その毛先を殺菌灯の方に向けて、傾いたりすることなく、ブラシ部の毛を殺菌光線の照射方向と平行またはほぼ平行に保つように位置固定する手段を意味する。

【0010】 歯ブラシ位置固定手段は、ケース内への歯ブラシの挿入、ケースからの歯ブラシの取り出し、および位置固定手段への脱着が容易に行い得るものであればどのような構造および形状であってもよく、歯ブラシケースの形状、歯ブラシケース内への歯ブラシの収納形式や収納構造、殺菌灯の種類や形態、殺菌灯の取り付け位置等に応じて、その形状、構造および配置位置を適宜選択することができる。

【0011】 そのうちでも、歯ブラシ位置固定手段としては、バネ弾性を有する挟持手段を採用するのが歯ブラシがきちん

【0012】また、他の形式としては、ケース内の懸垂板の凹部に懸垂された歯ブラシ、またはケース内の仕切られた個々の歯ブラシ室に立てて挿入された歯ブラシのブラシ部をその背面部分から押圧して、ブラシ部の毛が殺菌光線に対して平行になるようにする押圧手段を位置固定手段として歯ブラシケースの蓋や本体に取り付けてもよく、更にその他の形式であってもよい。

【0013】本発明では歯ブラシケースの形状は特に限定されず、扁平な弁当型、円筒型、箱型、ドーム型等の任意の形状にすることができる。また、歯ブラシケースの寸法も特に限定されず、本発明の歯ブラシケースを配置または取り付ける場所、歯ブラシケース内に収納する歯ブラシの本数等に応じて適宜設計するとよい。更に本発明の歯ブラシケースは、例えば1~2本の歯ブラシのみを収納する小型の携帯式の歯ブラシケースにしても、洗面台などに置く形式にしても、複数本（例えば4~5本）の歯ブラシを収納でき壁面に取り付ける形式にしても、または洗面ユニット、バスユニット等に組み込む形式にしてもよい。

【0014】また、歯ブラシケース内に取り付けられる殺菌灯の種類は特に限定されず、この種の装置で使用されている殺菌灯のいずれもが使用でき、紫外線灯、水銀灯、ケミカルランプ等を挙げることができる。紫外線灯の場合は、少なくとも150~400nmの波長領域の紫外線を効率よく放つ放電管であればよく、そのうちでも220~380nmの波長領域、特に250~260nmの波長領域の紫外線を放つ放電管が殺菌作用が大きく好ましい。また、これらの紫外線に一部可視光線が含まれていてもよい。そのような波長領域の紫外線を効率よく放ち且つコンパクトな殺菌灯を使用した場合には、歯ブラシケースを場所のとらないコンパクトなものにすることができる。

【0015】更に、殺菌灯は、棒状、U字管状、球状など任意の形状のものを使用することができる。具体例としては、例えば、三共電気（株）製カタログ「紫外線殺菌等」（875-5000）に記載されている種々の殺菌灯、特に小型のU字管型殺菌灯（GUL4、GUL5、GUL6等）および球状型殺菌灯（GTLwおよびGGT3.5等）、（株）東芝、照明事業部製、総合カタログ「TOSHIBAランプ」'88-9に記載されているブラックライト蛍光灯、捕虫用蛍光灯、健康線用蛍光灯等を挙げることができる。

【0016】歯ブラシケースの材質は特に限定されず、プラスチック、金属、木材、セラミックス、ガラス、それらの複合体等から形成することができる。特に、紫外線吸収剤を含有するプラスチックから歯ブラシケースを形成すると、ケース外への紫外線の漏れを防止することができ、安全性を高めることができ、また歯ブラシケースの洗浄なども簡単であり、望ましい。

【0017】そして特に、歯ブラシケース内に設ける歯

ブラシ位置固定手段がバネ弾性を有する挟持手段からなる場合は、挟持手段をバネ弾性があるかつ紫外線などの殺菌光線に強い材質から形成することが必要である。そして、その場合の挟持手段用の材質としては、金属、熱可塑性プラスチックなどを挙げることができ、熱可塑性プラスチックを使用する場合は、紫外線吸収剤を配合したポリプロピレンが耐紫外線性が極めて良好であり好ましい。

【0018】また、歯ブラシケースにおける歯ブラシの出し入れ口の位置は、ケースの上部、中間、下部、手前、横等のいずれにしてもよく、歯ブラシの出し入れ口の位置や、ケース内に収納する歯ブラシの本数等に応じて、ケース本体と蓋体の位置関係や形状を設計するのがよい。洗面場などに取り付けたり、配置して使用する歯ブラシケースの場合は、一般に、歯ブラシの出し入れ口を、歯ブラシケースの前面、上部または側面の設けるのが便利である。更に、本発明の歯ブラシケースでは、歯ブラシをケース内に収納した時に、ブラシ部が上で柄の部分が下になるように、またはブラシ部が下で柄の部分が上になるように設計しても、或いは歯ブラシを横に寝かせて収納するように設計してもよい。

【0019】そして、歯ブラシケース内への歯ブラシの収納形態に応じて、殺菌灯からの殺菌光線が歯ブラシのブラシ部に最も効率よく照射されるように、殺菌灯の種類、形状、サイズ、その取り付け位置を選択する必要がある。例えば、扁平な箱型の歯ブラシケース内に、複数本の歯ブラシをブラシ部が上で柄が下になり且つブラシ部の毛先がケースの奥に向いて並列して収納されるように設計されている歯ブラシケースでは、該扁平箱型歯ブラシケースの天井部分または上部の奥側に横長またはU字状の殺菌灯を横に寝かせて取り付け殺菌光線が歯ブラシのブラシ部に集中的に照射されるようにするとよい。また、例えば、ドーム型の歯ブラシケースの内周に沿って複数本の歯ブラシがそのブラシ部の毛先が中心に向いて収納されるように設計されているドーム型歯ブラシケースでは、ケースの中心部に球状、縦長状、またはU字状の殺菌灯を縦方向に取り付けて、周囲放射状に放出された殺菌光線が各歯ブラシのブラシ部に照射されるようにするのがよい。

【0020】特に、洗面場などに取り付けたり、置いて使用する扁平箱型の歯ブラシケースの場合は、使い勝手や収納時の安定性等の点から、ブラシ部が上で柄の部分が下になるように縦にして歯ブラシを収納する構造にすると共に、歯ブラシのブラシ部に近い位置に殺菌灯を取り付けるのが好ましい。

【0021】また、近年、歯ブラシとして極めて多種の製品が販売されており、歯ブラシの長さや、歯ブラシのブラシ部の長さが製品によってまちまちであり、歯ブラシのブラシ部が殺菌灯のある位置に必ずしもきちんとは当たらない場合がある。そのような場合に、本発明の歯ブラシ

ケースにおいて、歯ブラシのブラシ部が殺菌灯のある位置にきちんとくるように、歯ブラシの位置固定手段と共に歯ブラシの位置調節手段を更に設けると、その殺菌効果を一層向上させることができる。その際の位置調節手段としては、本出願人の出願に係る特願平3-341798号に記載されているものなどを採用することができる。

【0022】安全性の点から、本発明の歯ブラシケースは蓋体の開放時に殺菌灯を消灯させる手段を有しており、蓋体が閉じている時のみ殺菌灯が点灯するようになっているのがよい。その場合に、蓋体の閉じているときに常に殺菌灯が点灯している必要はなく、一日のうちの所定時間だけ殺菌灯を点灯させれば歯ブラシの殺菌を行うことができるので、歯ブラシケースの蓋体の開閉に連動して殺菌灯を自動的に点灯および消灯させる制御手段と共に、蓋体が閉じている時に殺菌灯を所定時間だけ点灯させその後は消灯させるタイマーを組み込んで、殺菌灯による殺菌を安全に且つ無駄なく効率的に自動的に行えるようにするのがよい。

【0023】上記の場合に、歯ブラシを使用する時間帯、すなわち歯ブラシケースが解放される時間帯は、朝、昼食後、夜等の所定の時間帯に通常集中するところから、歯ブラシケースが閉じられて後に直ちに殺菌灯が点灯するように電気回路を設計すると、歯ブラシケースの開閉の頻度が高いそれらの時間帯では、殺菌灯の点灯および消灯が短時間のうちに多数回繰り返されることになり、殺菌灯等の電気部品の早期消耗、電気の無駄な消費、ケースからの殺菌光線の漏れの危険等を招き易い。そのため、歯ブラシケースの蓋体が閉じられた後に直ちに殺菌灯を点灯させずに、該頻度の高い歯ブラシケースの開閉が終了した後の所定時間後に初めて殺菌灯が点灯して、所定時間点灯を継続した後にタイマーで消灯するようにする（例えば蓋体が閉じた後の30分後に殺菌灯が点灯して、約15秒〜3分間点灯を継続した後消灯させる）と、殺菌灯の点灯・消灯の頻度が少なくなり、電気部品の早期消耗、電気の無駄な消費、ケースからの殺菌光線の漏れの危険を防止することができる。その際に、そのような殺菌灯の点灯および消灯並びにタイマーの作動を、歯ブラシケースの蓋体の開閉に自動的に連動する1個のスイッチによって行うようにするのが好ましい。

【0024】そして、本発明の歯ブラシケースでは、各々の状況に応じて、その電源を電池、コンセントからの商用電源、またはそれらの両用のいずれとしてもよい。また、歯ブラシケースは、その性質上極めて湿度および水分の多い条件下で使用されるので、電気部品が湿度や水分から充分保護されるような構造とする必要があり、例えば歯ブラシの収納部とは完全に遮断された電気部品収納部を設けてそこに電気部品を収納するようにしてもよい。以下に、図面を参照して本発明の歯ブラシケース

の例を具体的に説明するが、本発明はそれにより限定されない。

【0025】《実施例 1》[歯ブラシケース①：偏平な箱型歯ブラシケース]

この歯ブラシケース①は、図1に示すような偏平な箱型の外観を有しており、外側のケース全体が例えば紫外線吸収剤を含有するアクリル樹脂などのプラスチックで作製されている。図2はケース1の蓋体を開いた時の歯ブラシの収納状態を示すものであり、図3はケース本体の前面を外した時のケース内における歯ブラシの収納固定状態を示す図である。また、図4は図1の歯ブラシケースをその中央部で切断した時の縦断面図である。図5はこの歯ブラシケース①で使用している、歯ブラシ懸垂兼位置固定手段を設けた歯ブラシホルダーの構造を示す図である。

【0026】この歯ブラシケース①は、後方部1aおよび前面部1bからケース本体1を形成し、その前面に上下方向に開閉可能に蓋体2を上部で枢止してある。ケース本体1を形成している後方部1aと前面部1bとは互いに分解・組立可能であり、歯ブラシケースが汚れた時に分解してその内部を清掃できるようにしてある。また、ケース本体1の前面部1bの上部中央には、蓋体2の解放を容易にするための凹状の手掛部3を設けてあり、更に紫外線灯への通電状態を示す表示ランプ4が設けてある。

【0027】ケース本体1内には、歯ブラシ5の首部分5aで歯ブラシをバネ弾性により挟持して位置固定する挟持手段6が横方向に複数個設けられた図5に示す歯ブラシホルダー7が着脱自在に取り付けてある。そして、歯ブラシホルダー7に設けた挟持手段6によって歯ブラシのブラシ部5bがケース本体1の上部奥に設けた紫外線灯8にほぼ平行に位置固定されて、紫外線がブラシ部5bの毛根部分にまで充分に照射されるようになっている。

【0028】挟持手段6をも含めて歯ブラシホルダー7の全体が紫外線吸収剤を配合した耐紫外線性の良好なポリプロピレンから一体に成形されており、ポリプロピレンの弾性によって歯ブラシ5の首部分5aを挟持手段6により挟持固定している。歯磨きの際には、歯ブラシ5を手前に引っ張ると、挟持手段6のバネ弾性によって挟持手段6を構成している2つの片6aと6bとの間が開くので、歯ブラシ5は挟持手段6から外れて、ケース本体1外に簡単に取り出すことができる。

【0029】この歯ブラシケース①では、ケース本体1の後方部1aおよび前面部1b、並びに歯ブラシホルダー7が各々別のパーツとしてプラスチックから作製されているので、ケースの内部が汚れた際に、それらを分解して簡単に清掃することが可能である。

【0030】また図4に示すように、蓋体2の内部には、蓋体2を閉じたときに歯ブラシ5を押さえて歯ブラ

シ5のブラシ部5bを紫外線灯8に近接させる突条9が設けてあり、この突条9は紫外線の下方への遮蔽作用をも有する。紫外線灯8はケース本体1の上部に横長に取り付けてあり、挟持手段6および突条9の共働作用によって、歯ブラシ5のブラシ部5bが紫外線灯8に対して平行に位置固定されて、紫外線がブラシ部5bの毛根部分まで一層良好に照射される。

【0031】この歯ブラシケース①では、挟持手段6は歯ブラシホルダー7にプラスチックにより一体に形成してあるが、これに限定されるものではなく、例えばケース本体の後方部1aの内壁に直接バネ弾性を有する挟持手段6を設けて、それによって歯ブラシ5をケース内に挟持固定するようにしてもよい。また、挟持手段6はプラスチックでなく、バネ弾性を有する金属片から形成してもよい。

【0032】更に、この歯ブラシケース①では、図4に示すように、ケース本体1と蓋体2との接合部分には、互いに重なり合うように重ね合わせ部10と11を設けて、紫外線がケース外に漏れないようにしている。この重ね合わせ部はケース本体1と蓋体2の接合部分の全周に亘って設けるのが好ましい。また、ケース本体1には、蓋体2の開閉に連動して殺菌灯8を点灯または消灯し、且つ上記したタイマーの作動をつかさどるスイッチ12を取り付けてある。

【0033】ケース本体1の背面には必要に応じて歯ブラシケースを壁やその他の箇所に取り付けられるようにフック13を設けてある。フックの数、形状、位置等は適宜変えることができる。フック13を利用してこの歯ブラシケース①を壁面に取り付けるに当たっては、歯ブラシケース①を直接そのままフック13によって壁面に取り付けてもよい。しかし、歯ブラシケース①とは別に歯ブラシケース①のフック13と係合する掛部を有する取り付け板(図示せず)を用意し、この取り付け板をネジや接着剤などによって壁面に固着し、この取り付け板の掛部に歯ブラシケース①のフック13を着脱自在に掛けるようにすると、必要な時に歯ブラシケース①を壁面から取り外すことが可能になり、歯ブラシケース①の清掃や電池交換などの部品の取り替えが容易になる。

【0034】ところで、歯ブラシケース①の取り付け部の構造は必ずしもフックである必要はなく、他の手段を採用してもよい。また、ケース本体の後部には、歯ブラシの出し入れや殺菌の邪魔にならないようにして、水分や湿分が入らないようにした密封した電気部品収納部14を設けてあり、電池やその他の電気部品が収納できるようにしてある。

【0035】更に、ケースの下部には、ケース本体の前面部1bと後方部1bとの間にスリット15を設けておき、そのスリット部分に水受けトレイ16を着脱自在に取り付け、水受けトレイ16に溜まった水をトレイ16を外して捨てるようにしてある。この実施例1の歯ブラ

シケース①は、コンパクトであって場所を取らず、狭い箇所にも容易に取り付けることができ、しかも歯ブラシのブラシ部に生息する菌類をほぼ100%の高率で殺菌することができる。

【0036】《実施例2》[歯ブラシケース②: 偏平な箱型歯ブラシケース]

上記実施例1におけるような後方部1aおよび前面部1bからなるケース本体1と上部に開閉可能な蓋体2を備えた歯ブラシケースにおいて、歯ブラシ5を懸垂手段によらず、図6および図7に示すように挿入形式でケース内に収納するようにしてもよく、その場合には、例えば蓋体2設けた突条9とケース本体1内に設けた突部17とで、歯ブラシ5のブラシ部5bを紫外線灯8に対してほぼ平行に位置固定する。

【0037】《実施例3》[歯ブラシケース③: 円筒型歯ブラシケース]

この歯ブラシケース③は、図8および図9により示される円筒型の歯ブラシケースであり、図8は歯ブラシケース③の縦断面図であり、図9は図8の切断線A-Aから見た歯ブラシケース③の平面図である。

【0038】この歯ブラシケース③は、下部のケース本体1および上部の蓋体2とからなり、蓋体2を上部に持ち上げてケースへの歯ブラシ5の出し入れを行うようになっている。ケース本体1の内部は、複数の歯ブラシホルダー7が放射状に設けてある。歯ブラシホルダー7の先端部には、歯ブラシ5を上部から挿入した時にそのバネ弾性によって外方に開いて径を大きくして歯ブラシ5の柄の部分挟持固定する歯ブラシの挟持手段6が設けてある。この歯ブラシケース③では殺菌灯8はケース本体の中央に取り付けてあり、放射方向に照射される殺菌光線がその周囲に位置する歯ブラシ5のブラシ部の各々に丁度照射されるようになっている。また、ケース本体1の底部1cはケース内の清掃が容易なように着脱可能に取り付けられており、そこにはケース内に溜まった水を外部に排出するための排水部18を設けてある。

【0039】ケース本体には、蓋体2の開閉に連動して殺菌灯8を点灯または消灯し、且つ上記したタイマーの作動をつかさどるスイッチ12を取り付けてある。そして、ケース本体の中央下部には、歯ブラシの出し入れや殺菌の邪魔にならないようにして、水分や湿分が入らないようにした密封した電気部品収納部14を設けてあり、電池19やその他の電気部品が収納できるようにしてあり、この収納部14は蓋20等により外部から開閉可能になっている。この実施例3の歯ブラシケースは、安定性がよく、適当な場所に載置して使用することができる。更に、ケース本体1には、蓋体2を閉じた時にケース本体1と蓋体2が互いに重なり合って接合されるように突条21がその開口部全周に亘って設けられており、これによって紫外線のケース外への漏れを防止することができる。

【0040】上記の実施例2および実施例3の歯ブラシケースでは、ケース内の底部またはその近辺の歯ブラシ挿入位置に、図示していないが、先に挙げた特願平3-341798号に記載されているような歯ブラシの高さ位置を調節する調節手段を必要に応じて設けておいてもよく、それによって、歯ブラシの長さが異なっても、そのブラシ部を殺菌光線の照射位置に適確に位置させることができ、一層殺菌効果が向上する。

【0041】《実施例 4》〔携帯用歯ブラシケース〕

図10は、紫外線吸収剤を添加したプラスチックなどから形成されたケース本体1と蓋体2とからなる、ペンシルケース程度の大きさを有する殺菌灯付きの携帯用の歯ブラシケースの略図を示したものである。ケース本体1の内側には、小さな紫外線灯8を取り付けてある。ケース本体1内の底部分には、更にバネ弾性を有する弾性挟持片6aおよび6bかならなる挟持手段6が複数個設けてあり、それらの挟持手段6によって歯ブラシ5の首部分5aや柄の部分の部分を強固に挟持して、歯ブラシのブラシ部5bが紫外線照射部位に適確に位置させる。この携帯用歯ブラシケースにおいて、図示していないが、蓋体2の開

【0042】

【発明の効果】本発明の歯ブラシケースは、歯ブラシ位置固定手段を備えているので、歯ブラシのブラシ部の毛先を殺菌灯の方に向けて、傾いたりせずに殺菌灯に対して平行またはほぼ平行に保つように位置固定することができ、それによって菌類の繁殖の一番多いブラシ部の毛根部分にまで殺菌光線を照射することができ、歯ブラシの殺菌を完全に行うことができる。特に、歯ブラシ位置固定手段として、バネ弾性を有する挟持手段を使用した場合には、歯ブラシの位置固定と共にその脱着を容易に且つ円滑に行うことができる。

【図面の簡単な説明】

【図1】実施例1における扁平な箱型の殺菌灯付き歯ブラシケースの外観の一例を示す図である。

【図2】図1の歯ブラシケースの蓋体を開いたときの歯ブラシの収納状態を示す図である。

【図3】図1の歯ブラシケースのケース本体前面を外したときの図である。

【図4】図1の歯ブラシケースをその中央部で切断した時の縦断面図である。

【図5】図1の歯ブラシケースで使用する歯ブラシホルダーの一例を示す図である。

【図6】実施例2の歯ブラシケースのケース本体前面を外したときの図である。

【図7】図6の歯ブラシケースをその中央部で切断した時の縦断面図である。

【図8】実施例3における円筒型の殺菌灯付き歯ブラシケースの縦断面図である。

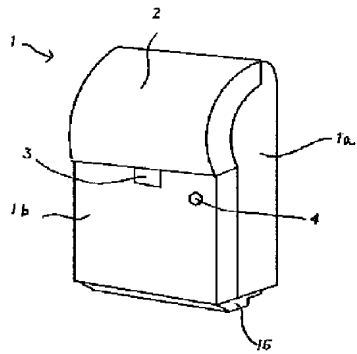
【図9】図8の歯ブラシケースを切断線A-Aより見た平面図である。

【図10】本発明の殺菌灯付き携帯用歯ブラシケースの一例を示す図である。

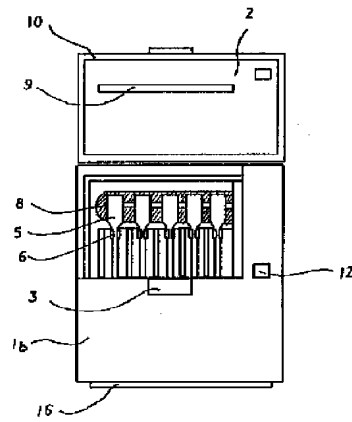
【符号の説明】

- | | |
|----|------------|
| 1 | ケース本体 |
| 1a | 後方部 |
| 1b | 前面部 |
| 1c | 底部 |
| 2 | 蓋体 |
| 3 | 手掛部 |
| 4 | 表示ランプ |
| 5 | 歯ブラシ |
| 5a | 歯ブラシの首部分 |
| 5b | 歯ブラシのブラシ部 |
| 6 | 挟持手段 |
| 6a | 挟持片 |
| 6b | 挟持片 |
| 7 | 歯ブラシホルダー |
| 8 | 紫外線灯または殺菌灯 |
| 9 | 突条 |
| 10 | 重ね合わせ部 |
| 11 | 重ね合わせ部 |
| 12 | スイッチ |
| 13 | フック |
| 14 | 電気部品収納部 |
| 15 | スリット |
| 16 | 水受けトレイ |
| 17 | 突部 |
| 18 | 排水部 |
| 19 | 電池 |
| 20 | 蓋 |
| 21 | 突条 |

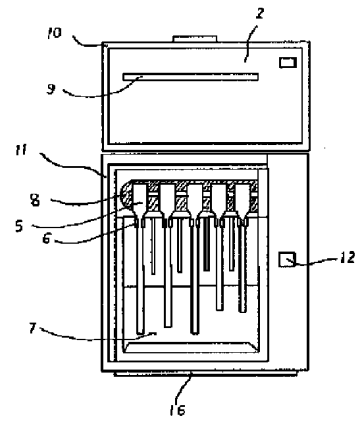
【図1】



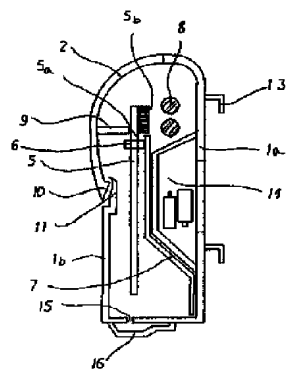
【図2】



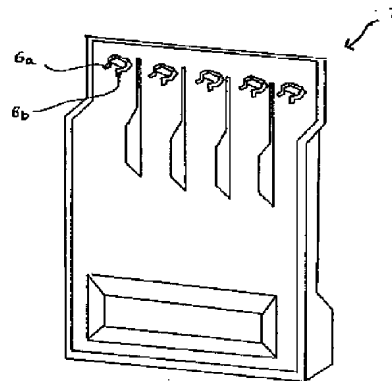
【図3】



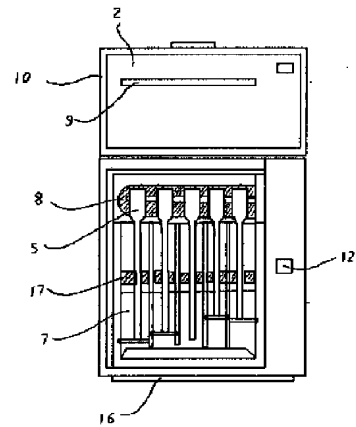
【図4】



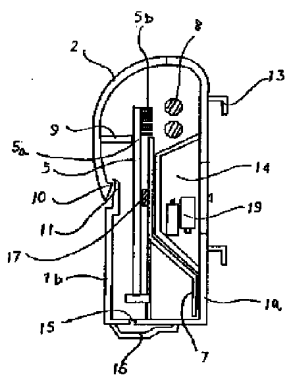
【図5】



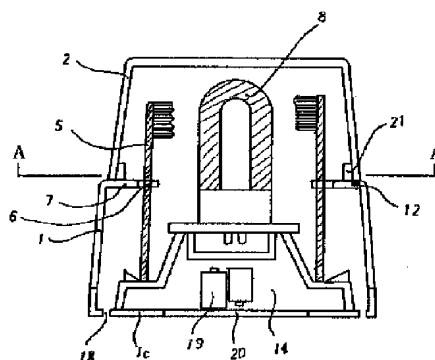
【図6】



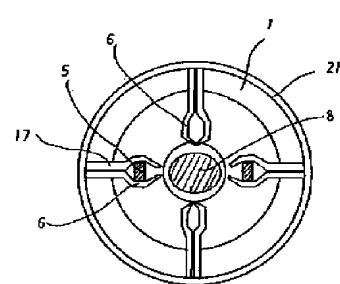
【図7】



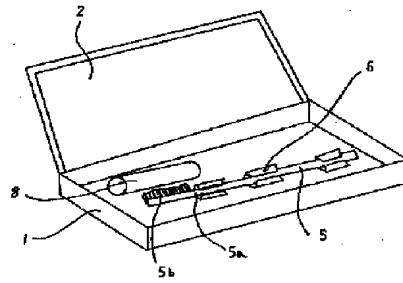
【図8】



【図9】



【図10】



LASER TREATMENT APPARATUS

Publication number: JP9084803 (A)

Publication date: 1997-03-31

Inventor(s): NAKAMURA TOSHIHISA; HATTORI TOMOHIKO

Applicant(s): TERUMO CORP

Classification:

- **international:** **A61B18/20; A61N5/06; A61B18/20; A61N5/06;** (IPC1-7): A61B17/36; A61N5/06

- **European:**

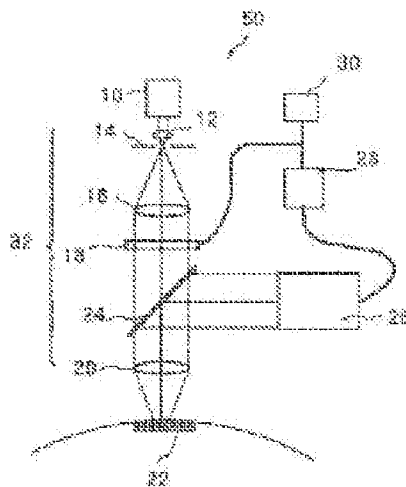
Application number: JP19950249509 19950927

Priority number(s): JP19950249509 19950927

Abstract of JP 9084803 (A)

PROBLEM TO BE SOLVED: To obtain a laser treatment apparatus enabling selective irradiation by arbitrarily changing the shape of the mask set to an irradiation optical system on the basis of the modified image of the image of the lesion part on the imaged surface of the body or body cavity.

SOLUTION: The laser beam emitted from a laser oscillator 10 is expanded by a beam expander to be collimated by a collimate lens 16 to reach the surface of a lesion part 22 by an irradiation optical system 32. The laser beam transmitted through the shape changeable mask 18 arranged to the irradiation optical system 31 is condensed to the surface of the lesion part 22 by a condensing lens 20 to perform laser treatment matched with the shape of the mask 18. At this time, the reflected beam from the surface of the lesion part 22 is taken out of the irradiation optical system 32 by a half mirror 24 to be guided to a television camera 26. Herein, the shape of the shape changeable mask 18 is altered and the adjustment of a light cut-off region is performed to control the laser treatment shape on the surface of the lesion part 22.



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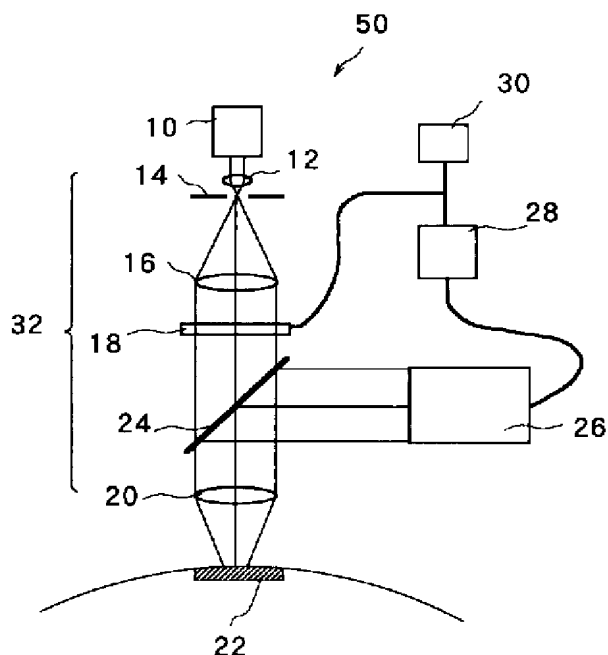
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(54)【発明の名称】 レーザ治療装置

(57)【要約】

【課題】レーザ治療装置内の照射光学系にセットしたマスクの形状を、撮像した病変部の変調像により任意に変化させることの可能なレーザ治療装置を提供する。

【解決手段】レーザ光を照射するレーザ光源10と、レーザ光を病変部22表面に集光する照射光学系32と、病変部22表面で反射されたレーザ光を照射光学系32から取り出す撮像光学系24と、撮像光学系24により取り出されたところの病変部22表面で反射された反射光を撮像するカメラ26と、照射光学系内32に設けられ、レーザ光の病変部22表面への照射形状を変更する形状可変マスク18と、カメラ26により撮像された画像に基づいて、形状可変マスク18によるレーザ光の照射形状変更動作を制御する制御装置28とを具備する。



【特許請求の範囲】

【請求項1】 レーザ光を照射するレーザ光源と、前記レーザ光を病変部に集光する照射光学系と、前記病変部の映像を取り出す撮像光学系と、該撮像光学系により取り出されたところの前記病変部表面で反射された反射光を撮像するカメラと、前記照射光学系内に設けられ、前記レーザ光の前記病変部表面への照射形状を変更する形状可変マスクと、前記カメラにより撮像された画像に基づいて、前記形状可変マスクによるレーザ光の照射形状変更動作を制御する制御装置とを具備することを特徴とするレーザ治療装置。

【請求項2】 前記形状可変マスクは、液晶を用いて前記レーザ光の透過形状を変更するマスクであることを特徴とする請求項1に記載のレーザ治療装置。

【請求項3】 前記形状可変マスクは、ファインセラミックスを用いて前記レーザ光の透過形状を変更するマスクであることを特徴とする請求項1に記載のレーザ治療装置。

【発明の詳細な説明】**【0001】**

【発明の属する技術分野】本発明は体表面もしくは体腔内病変部にマスクを介したレーザ光を照射しレーザ治療を行うレーザ治療装置に関する。

【0002】

【従来の技術】従来より、レーザの持つ単色性、指向性、収束性、高輝度性等の優れた光学特性を利用して生体組織の治療への適用が盛んになされ、病変部の切除、血液凝固、組織凝固等の治療が行われている。これらのレーザ治療においては、照射するレーザの波長とエネルギー密度、そして被照射物である生体組織の光学特性および、治療行為の種類によって適当な装置が選択され用いられてきた。しかしながら、いずれの装置を用いた場合にもレーザ照射部位の制御は難しく、病変部のみに照射を行い周辺の正常組織に影響を及ぼさないようにするには、レーザ光を絞り、病変部周囲の正常組織にはレーザを当てないようにすることが必要であった。そのため術者は、かなりの注意と労力を払わねばならなかった。また組織の凝固のように、レーザのビーム径を極端には絞らずに生体組織の比較的広い面積に照射する場合などは、部分的に存在する正常組織にまでレーザ照射してしまうことがあった。これを避けるためには、複数の箇所に分割して正常組織を残すようにレーザ照射をする必要があった。

【0003】

【発明が解決しようとする課題】従って、本発明は上述した課題に鑑みてなされたものであり、レーザ治療装置の照射光学系にセットしたマスクの形状を、撮像した体表面もしくは体腔の病変部映像の変調像により任意に変化させることで選択照射の可能なレーザ治療装置を供給

することを目的とする。

【0004】

【課題を解決するための手段】上述した課題を解決し目的を達成するために、本発明に係わるレーザ治療装置は、レーザ光を照射するレーザ光源と、前記レーザ光を病変部に集光する照射光学系と、前記病変部の映像を取り出す撮像光学系と、該撮像光学系により取り出されたところの前記病変部表面で反射された反射光を撮像するカメラと、前記照射光学系内に設けられ、前記レーザ光の前記病変部表面への照射形状を変更する形状可変マスクと、前記カメラにより撮像された画像に基づいて、前記形状可変マスクによるレーザ光の照射形状変更動作を制御する制御装置とを具備することを特徴としている。

【0005】また、この発明に係わるレーザ治療装置において、前記形状可変マスクは、液晶を用いて前記レーザ光の透過形状を変更するマスクであることを特徴としている。

【0006】また、この発明に係わるレーザ治療装置において、前記形状可変マスクは、ファインセラミックスを用いて前記レーザ光の透過形状を変更するマスクであることを特徴としている。

【0007】

【発明の実施の形態】以下、本発明の好適な一実施形態について、添付図面を参照して詳細に説明する。

【0008】図1は、一実施形態のレーザ治療装置の基本構成を示す図である。

【0009】図1において、レーザ治療装置50は、レーザ光を発振するレーザ発振器10と、レーザ発振器10から照射されたレーザ光を拡大するための凸レンズからなるビームエキスパンダ12と、ビームエキスパンダ12から出射した光の散乱光を除去するための空間フィルタ14と、ビームエキスパンダ12で拡大されたレーザ光を平行光に戻すためのコリメートレンズ16と、コリメートされたレーザ光の形状を病変部22の治療に必要な所望の形状に成形するための形状可変マスク18と、形状可変マスク18を通過したレーザ光を集光するための集光レンズ20とを備えている。また、形状可変マスク18と集光レンズ20との間には、病変部22の表面で反射されたレーザ光をテレビカメラ26に導くためのハーフミラー24が設けられている。テレビカメラ26には制御装置28が接続されており、テレビカメラ26で撮像した映像に基づいて、形状可変マスク18を制御する。また、制御装置28にはテレビモニタ30が接続されており、テレビカメラ26で撮像された映像を術者が観察できるようになされている。

【0010】このように構成されるレーザ治療装置は、以下のように動作する。

【0011】即ち、レーザ発振器10より照射されたレーザ光はビームエキスパンダ12にて拡大され、コリメートレンズ16によりコリメートされた後、照射光学系

32により病変部22の表面に達する。照射光学系32に設置された形状可変マスク18を透過したレーザ光を集光レンズ20にて病変部22の表面に集光させることでマスク18の形状に合わせたレーザ治療を行う。この時ハーフミラー24によって、病変部22の表面からの反射光を照射光学系32から取り出し、病変部22の表面の状態を観察できるように、テレビカメラ26に導く。テレビカメラ26により取り込んだ病変部22の表面の映像は制御装置28による演算処理後、変調像とし形状可変マスク18に入力される。これにより形状可変マスク18のマスク形状の変更を行い、遮光部位の調整を行って病変部22の表面でのレーザ治療形状の制御を行う。すなわち、テレビカメラ26で撮像された所の、病変部22の表面形状及びその表面におけるレーザ光の照射形状が病変部22上を治療しようとする形状に適さない場合は、形状可変マスク18の光透過状態を変更し、レーザ光の照射形状及び照射強度を治療に適したものとなるよう制御する。このとき、テレビモニタ30に接続することで、病変部22の表面の映像および形状可変マスク18に入力する変調像を観察する。マスク18への病変部22の変調像の入力は連続的もしくは段階的に行うことで、レーザ照射にともない病変部形状が変化する場合にも効果的な治療を行うことが出来る。なお各構成部材の位置、大きさおよび形状は本発明の趣旨に反しない限り任意である。また、本発明に基づくレーザ治療装置において発振、及び治療に用いるレーザの波長は任意であり、レーザ照射光学系と撮像光学系において必ずしも同一波長である必要はない。また、撮像系での病変部観察は可視光に限定されるものではなく病変部組織によって発する励起光等を位置検出の手段としても良い。

【0012】また、図2に示すような反射鏡80と中空管81、関節部82及び集光レンズ83を組み合わせたアーム状放射部や、図3に示すような光ファイバ、中空導波路、薄膜導波路などの導光部材84及び集光レンズ85で構成される可撓性チューブ状放射部を用いることにより体腔内病変部の治療も可能となる。次に、図4、図5に変調像を入力することでレーザ遮光部位の形状を変化させることの可能な、形状可変マスク18の構成例を示す。

【0013】図4に示すように、一対の透明電極40及び偏光方位角の直交する一対の偏光板42の間に、透過光の偏光特性を変化させることの可能な光透過性の強誘電ファインセラミックスである例えばPLZT[(Pb, La)(Zr, Ti)O₃]、あるいはTN液晶44を挟むことにより光学素子46を構成する。この光学素子46が形状可変マスク18の1画素を構成する。すなわち、光学素子46を、図5のようにマトリックス状に配置し、個々の光学素子46に加工物22の表面の映像の変調像を入力することで、レーザ透過位置、遮光位置の制

御及び透過の割合の制御を行い形状可変マスク18とする。形状可変マスクの本体及び各構成部品の位置、大きさ、形状は本発明の趣旨に反しない限り任意である。

【0014】また、上記の実施形態のような偏光を利用して透過光の制御を行う光学素子以外にも透過及び散乱特性を利用した光学素子を用いて形状可変マスクを構成しても良い。図6に示すように、屈折率異方性のある液晶等の媒体60を適当に分散させた媒体62を二枚の透明電極64で挟み込み、照射した光の透過、散乱を電場によって制御する光学素子を、マトリックス状に配置する。このマトリックスの後方に集光レンズ66とアパーチャー68及びアパーチャー68を通過した光を再び平行光にするためのレンズ70を配置する。そして、上記の光学素子各々に加工物22の表面の映像の変調像を入力することで、形状可変マスクとする。形状可変マスクの本体及び各構成部品の位置、大きさ、形状は本発明の趣旨に反しない限り任意である。

【0015】

【発明の効果】以上説明したように、本発明によれば、病変部の映像を撮像光学系より取り込み、この映像の変調像を形状可変マスクに入力することにより、マスクを介してのレーザ治療における照射面形状及び照射強度を制御することが出来る。

【0016】

【図面の簡単な説明】

【図1】本発明の一実施形態のレーザ治療装置の構成例を示した図である。

【図2】アーム状レーザ放射部の構成を示す図である。

【図3】可撓性チューブ状レーザ放射部の構成を示す図である。

【図4】偏光を利用して透過光の制御を行う光学素子の構成例を示した図である。

【図5】形状可変フィルタの構成例を示した図である。

【図6】透過及び散乱特性を利用した光学素子の説明図である。

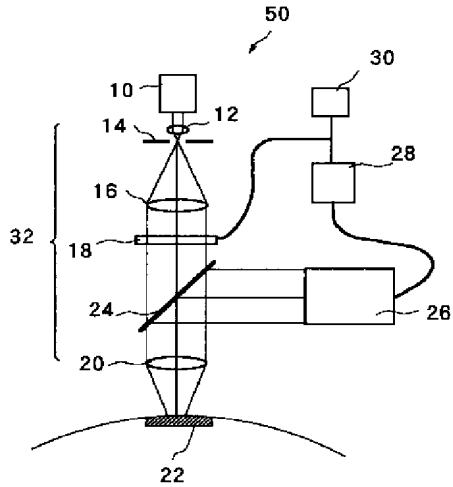
【符号の説明】

- 10 レーザ発振器
- 12 ビームエキスパンダ
- 14 空間フィルタ
- 16 コリメートレンズ
- 18 形状可変フィルタ
- 20 集光レンズ
- 22 病変部
- 24 ハーフミラー
- 26 テレビカメラ
- 28 制御装置
- 30 テレビモニタ
- 32 照射光学系
- 40 透明電極
- 42 偏光板

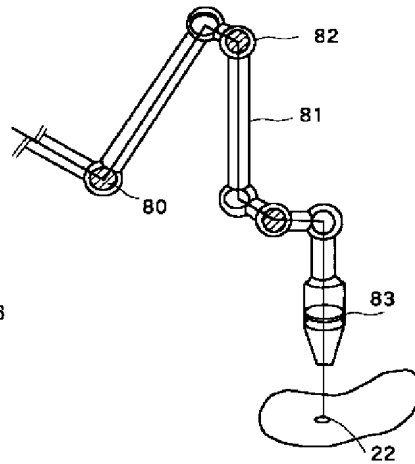
44 透過光の偏光特性を変えることの可能な物質
 46 光学素子
 50 レーザ治療装置
 60, 62 媒体

64 透明電極
 66 集光レンズ
 68 アパーチャー

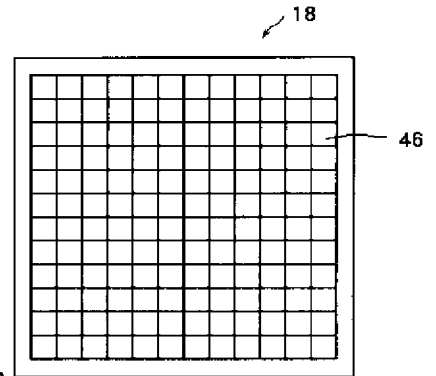
【図1】



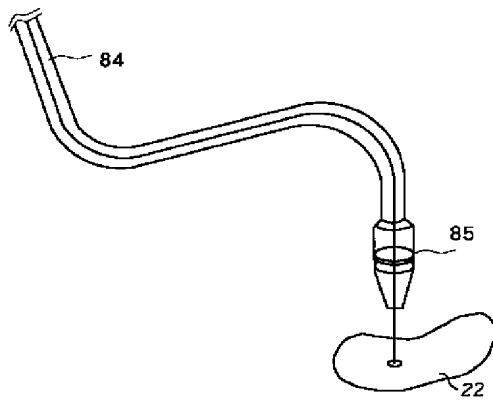
【図2】



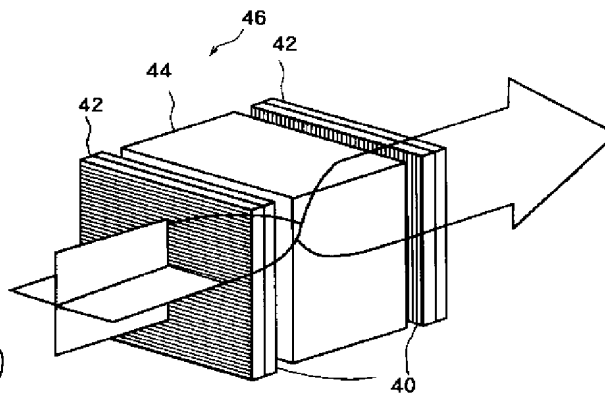
【図5】



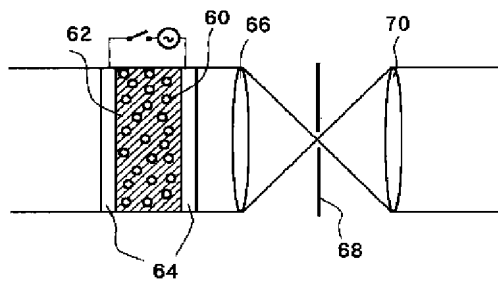
【図3】



【図4】



【図6】

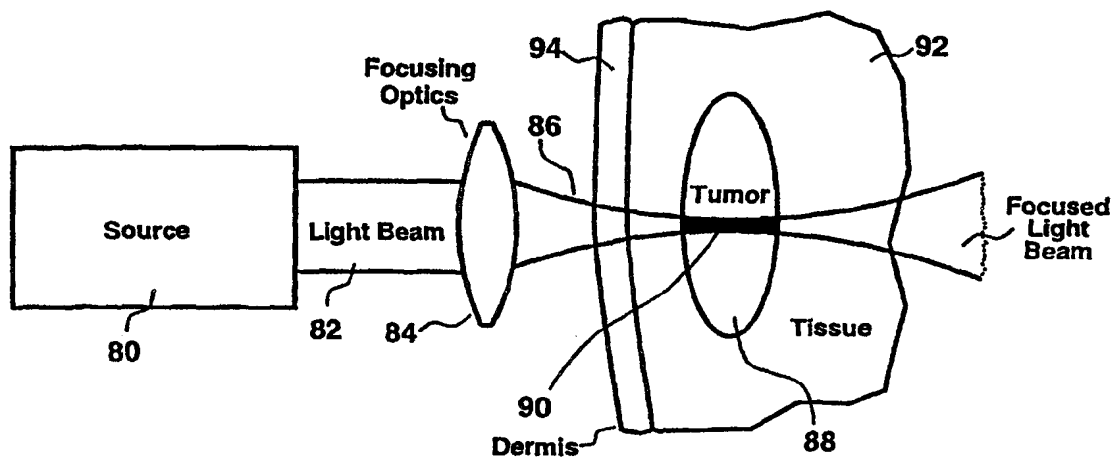




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(54) Title: TREATMENT OF PIGMENTED TISSUES USING OPTICAL ENERGY



(57) Abstract

This invention is a method, and apparatus for selectively photo-bleaching or killing pigmented tissues by photochemically converting pigments in the tissues using light (82), and specifically two photon excitation. Photo-toxic products thereby produced then kill pigmented cells. Hyperthermia or an exogenous agent can also be added to augment efficacy. The present invention is also directed to selective thermal destruction of pigmented tissues using related optical means.

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**TREATMENT OF PIGMENTED TISSUES
USING OPTICAL ENERGY**

BACKGROUND OF THE INVENTION

This is a continuation-in-part of U.S. Patent Application No. 08/739,801, filed on October 30, 1996, entitled "Method for Improved Selectivity In Photoactivation of Molecular Agents".

The present invention is directed to a method and apparatus for treating pigmented tissues by selective photoactivation of pigments in such tissues using optical energy and more specifically two-photon excitation. This selective photoactivation may be used to effect photobleaching of such pigments or to effect photochemical conversion of such pigments into phototoxic products. Photobleaching reduces or eliminates undesirable pigmentation, for example that caused by pigments present in moles, freckles, hair follicles and tattoos. Photochemical conversion produces phototoxic products that destroy pigmented tissues, such as those pigmented tissues in pigmented tumors. The present invention is also directed to selective thermal destruction of pigmented tissues using related optical means.

Photobleaching is the transient or permanent reduction of pigmentation in pigmented tissues upon optical illumination, typically occurring during intense illumination with visible or ultraviolet light. Photobleaching occurs when photoactive pigments are photochemically transformed from a highly colored state to a less highly colored state (depigmentation). For example, photobleaching may be used to reduce or eliminate undesirable pigmentation present in moles and hair follicles or to destroy dyes present in tattoos. It is desired that treated tissues will exhibit localized depigmentation without side effects, such as irritation or cell necrosis. However, previous methods for photobleaching tissues using visible or ultraviolet light have produced undesirable collateral effects, including irritation of surrounding tissues and possible scarring at the treatment site.

In contrast to photobleaching, photochemical conversion of pigments into phototoxic products involves stimulation of localized cell necrosis in treated tissues. This is also effected by optical illumination, typically occurring when intense visible or ultraviolet light is used to illuminate susceptible pigmented tissues. Such localized necrosis may be useful for selective destruction of diseased tissues, such as those present in tumors or benign skin lesions.

More specifically, an important subset of pigmented tissues are pigmented tumors, such as melanomas, which are life threatening and highly difficult to treat. While

melanomas can be treated if detected early using standard surgical, radiation or chemotherapeutic methods, these methods still do not have acceptable levels of effectiveness and produce high levels of collateral damage to normal tissue. Hence, even if detected relatively early, the prognosis is usually poor.

5 Further, if a melanoma has metastasized beyond the primary tumor site, less than 20% of patients will survive beyond five years. For such melanomas, there are no effective therapies. Patients diagnosed with such a metastatic melanoma will survive on average only 3-6 months after the diagnosis even with therapeutic intervention.

10 Further exacerbating the difficulties in treating melanomas is the fact that the incidence of melanoma in Caucasians is increasing at a rate of 6% per year. This is currently the second fastest rate of increase in cancer occurrences -- second only to tobacco related cancers of the lung in women. Currently, the lifetime risk of melanoma in the U.S. is 1 in 75. Accordingly, new effective therapeutic modalities are required to treat both primary and metastatic pigmented tumors such as melanomas.

15 One possible approach for treating pigmented tissues involves the use of melanins, their precursors, and other endogenous or exogenous pigments.

More specifically, there are several pigments in humans that are collectively known as melanins. The function of melanins are to protect tissues from the deleterious effects of electromagnetic radiation (e.g. light). However, melanins and their precursors can also
20 be converted to phototoxic products. For example, a melanin precursor (5-SCD) has been shown to photobind to DNA after exposure to 300 nm (ultraviolet light) illumination. Further, 5-SCD has been shown to be chemically unstable in the presence of ultraviolet (UV) illumination and oxygen, thereby suggesting that phototoxic products of the (1) Type I variety (phototoxic) or the (2) Type II variety (photocatalytic) may be produced.

25 Additionally, many melanoma cells are amelanotic. These cells produce melanin precursors but only small quantities of melanin. Phototoxic damage (induction of single strand breaks) to DNA by at least two precursors to melanin (5-SCD and DIHCA) has been demonstrated upon exposure to UV light. Amelanotic cells will be killed by photodynamic therapy (PDT) performed on such precursors to melanin (e.g., 5-SCD,
30 DIHEA). Thus, melanomas can be killed by delivering energy via light.

However, utilization of such phototoxic reactions by illumination of melanin, melanin precursors, or other endogenous pigments has not previously been possible. The UV/Near UV light required for photoactivation is unable to penetrate into normal or

5 cancerous skin (i.e. beyond 2-3 mm.) More specifically, the poor penetration of such light has produced little effect on patients whose skin tumors are larger than or at a depth greater than 3 mm. As a result, only 40-50% of patients whose tumors exceed 3 mm will survive. Accordingly, the survival rate of melanoma patients with tumors whose depth is less than 1 mm is drastically better than those who have tumors which are either located at a depth of greater than 3 mm or extend to a depth greater than 3 mm.

10 Previous photodynamic methods using UV/Near UV light also produced undesirable collateral effects that not only prohibited the photoconversion of melanin and prevented it from killing pigmented tissues but also was potentially dangerous to the patient. For example, UV light can create thymidine dimers which damage genetic material. DNA damage is a major and possibly the sole cause of skin cancers like melanomas. Melanin's absorbance of UV light is designed to prevent this from happening. However, UV light, chemotherapy, and ionizing radiation have recently been shown to increase the virulence of tumor cells. As a result, tumor cells when treated with UV light will have a greater mutation and error rate because the UV light can inactivate mechanisms designed to identify and correct genetic errors (in addition to creating new errors). Therefore, prior techniques were not only unable to effectively kill pigmented tissues by accessing endogenous pigments but also created side effects that could be lethal.

15 In many instances, the effectiveness of various photodynamic processes have been found to be markedly increased by simultaneous photoactivation and localized heating (hyperthermia). Typically, by heating the treatment zone 2-10°C above normal temperatures, the effectiveness of PDT is increased many fold. Such heating alone, however, has not been shown to produce a significant therapeutic effect. In contrast, the inventors of the present invention have conceived that more acute localized heating (i.e., > 2-10°C temperature rise) of tissues and tissue components within the treatment zone may produce a therapeutic effect by causing thermal overload in the treated tissues.

20 Therefore, it is an object of the present invention to provide a method for accessing endogenous pigments in pigmented tissues so as to be able to selectively photobleach said pigments.

25 It is another object of the present invention to provide a method for accessing endogenous pigments in pigmented tissues so as to be able to photochemically convert said pigments into phototoxic products.

It is another object of the present invention to provide a method that will access said endogenous pigments in pigmented tissues without accessing endogenous pigments in healthy tissues surrounding said pigmented tissues.

It is another object of the present invention to provide a method that will augment the effectiveness of said photochemical conversion of said endogenous pigments in said pigmented tissues through the localized application of hyperthermia in said pigmented tissues.

It is another object of the present invention to provide a method that will photothermally destroy pigmented tissues without harming healthy tissues surrounding said pigmented tissues.

SUMMARY OF THE INVENTION

The present invention is directed to a method and apparatus for treatment of a particular volume of tissue or material containing an endogenous pigment. In general, typically, the present invention uses the unique properties of simultaneous two-photon excitation with endogenous pigment in a particular volume of tissue, such as a tumor, to selectively photoactivate the pigment.

This photoactivated pigment may thereby be photobleached or photochemically converted into a phototoxic product. Such photoactivation results from the simultaneous two-photon excitation of the pigment. Preferably, the photons responsible for photoactivation are provided by a laser which produces a beam of light comprising a train of one or more ultrashort pulses. This beam of light can be a focused beam of light if the location and extent of the particular volume of tissue to be treated is precisely known. The focused beam of light can then be scanned throughout the volume of the tissue to treat the entirety of the pigmented tissue. Alternatively, where the location and extent of the pigmented tissue in a volume of tissue is not precisely known, a non-focused light beam can be used.

In an alternative embodiment, an exogenous photodynamic agent can be added to the particular volume of tissue. The exogenous agent can be photoactivated by the simultaneous two-photon excitation. Activation of the exogenous photodynamic agent augments the effectiveness of the endogenous pigment.

In a further alternate embodiment of the invention, the effectiveness of such photoactivation is augmented through the localized application of hyperthermia in the pigmented tissues.

In an additional further alternative embodiment of the invention, the particular volume of tissue is treated with light to promote thermal overload of the pigmented tissues. Thermal overload heats and kills the pigmented tissues.

BRIEF DESCRIPTION OF THE DRAWINGS

In describing the preferred embodiments, reference is made to the accompanying drawings:

FIGURE 1 illustrates an example energy level diagram for simultaneous two-photon excitation;

FIGURE 2 illustrates an example of absorption and scattering properties for animal tissue covering the ultraviolet to infrared spectral region;

FIGURE 3 shows the general trends in optical absorption properties of animal tissue for short wavelength and long wavelength light;

FIGURE 4 illustrates a comparison of optical activation in tissue when single-photon and two-photon excitation methods are used;

FIGURE 5 illustrates an embodiment of the present invention for selective two-photon photoactivation of melanin, melanin-precursors or endogenous pigments using focused light;

FIGURE 6 illustrates an another embodiment for selective two-photon photoactivation of melanin, melanin-precursors, or endogenous pigments using focused light;

FIGURE 7 illustrates a further embodiment for selective two-photon photoactivation of melanin, melanin-precursors, or endogenous pigments using non-focused light;

FIGURE 8 illustrate still another embodiment for selective two-photon photoactivation of melanin, melanin-precursors, or endogenous pigments in a subsurface tissue using non-focused light;

FIGURE 9 illustrates an alternate embodiment for the present invention wherein a focused light beam is used to thermally overload and kill pigmented tumor cells; and

FIGURE 10 illustrates another alternate embodiment for the present invention wherein a non-focused light beam is used to thermally overload and kill pigmented tumor cells.

DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENT

The present invention is directed to a method and apparatus for treating pigmented tissues using light. Such treatment includes the following photochemical outcomes of

therapeutic value: (1) the elimination of undesirable pigmentation in pigmented tissues through photobleaching; and (2) the permanent destruction of pigmented tissues through photochemical conversion of pigments into phototoxic products. More specifically, simultaneous two-photon excitation is used to photochemically convert endogenous or exogenous pigments into desired photoactive products, resulting in the desired photobleaching or tissue destruction. Photobleaching is used to reduce or eliminate undesirable coloration of tissue, such as that in moles, freckles, hair follicles and tattoos. The production of phototoxic products may be used to preferentially kill pigmented tumor cells or other undesirable tissues while sparing normal cells. Significantly, the methods and apparatus in the present invention used for photobleaching and production of phototoxic products utilize equivalent photoactivation mechanisms, differing substantially only in the intended treatment target.

In the preferred embodiment, the present invention uses simultaneous two-photon excitation to photoactivate pigments in the pigmented tissues, yielding photobleached or phototoxic products.

In an alternate preferred embodiment, the present invention uses related optical means to selectively destroy pigmented tissues via photothermal means.

Simultaneous Two Photon Excitation

"Simultaneous two-photon excitation" is the non-linear optical excitation occurring as a result of the essentially simultaneous interaction of two photons originating from a single ultrashort laser pulse with one or more agents or pigments to produce one or more photoactivated agents or pigments. "Non-linear optical excitation" means those excitation processes involving the essentially simultaneous interaction of two photons with one or more agents or pigments. "Essentially simultaneous interaction" means those excitation processes occurring as a result of the interaction of one or more agents or pigments with photons provided by a single ultrashort laser pulse. Ultrashort means less than approximately 10 ns.

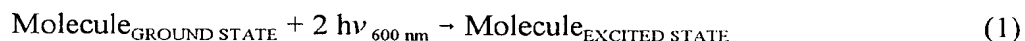
As shown in Figure 1, simultaneous two-photon excitation to an allowed energy level 10 occurs when a photoactive agent is excited from a first allowed electronic energy level 16 upon absorption of a certain energy E_1 that is provided by the simultaneous, combined interaction of two photons 12 and 14 with the agent. If the energies of both photons 12 and 14 are identical, the excitation process is termed "degenerate". The

simultaneous interaction of the two photons is frequently described as being mediated by a transient virtual state 20 with a lifetime on the order of 10 femtoseconds (fs) or less. If both photons do not interact with the agent during this lifetime, excitation does not occur and the agent fails to reach the excited state S_n (18). Typically, intersystem crossing, IX, subsequently occurs to bring the excited agent to a long-lived activated state T_m from which a photochemical reaction R can occur.

Simultaneous two-photon excitation may thereby be used to excite processes that normally occur upon absorption of a single UV or visible photon through the simultaneous absorption of two near-infrared photons.

An example of the simultaneous two-photon excitation process is the promotion of melanin precursors from a ground electronic state to an excited electronic state through the simultaneous absorption of two photons at 600 nm, followed by binding of the excited melanin precursor to DNA (this is conventionally excited using a single photon at 300 nm).

In this example, the probability of excitation is related to the product of the instantaneous or peak powers of the first of two photons 12 and the second of two photons 14. This can be conceptualized in the form of a photochemical reaction,



which shows that a molecule in the ground state is promoted to an excited state following simultaneous absorption of two photons at 600 nm, $h\nu_{600 \text{ nm}}$. The reaction rate R , is given by $R = k [\text{Molecule}_{\text{GROUND STATE}}] [h\nu_{600 \text{ nm}}]^2$, where k is a rate constant and where $[\text{Molecule}_{\text{GROUND STATE}}]$ and $[h\nu_{600 \text{ nm}}]$ symbolize concentrations of ground state molecules and excitation photons, respectively. Hence, due to the well known quadratic dependence on instantaneous photon irradiance, simultaneous two-photon excitation to an allowed energy level 10 is also referred to as a non-linear excitation process.

A more detailed explanation of simultaneous two-photon excitation and other non-linear and linear processes is described in U.S. patent application no. 08/739,801 filed October 30, 1996 for "Method For Improved Selectivity In Photoactivation Of Molecular Agents" assigned to the same assignee of the present application and which is incorporated herein by reference.

Significance of absorbance and scattering properties in single-photon and simultaneous two-photon processes:

While the cross-section for simultaneous two-photon excitation may be considerably lower than that observed with single-photon excitation, use of the simultaneous two-photon excitation in the present invention may be favorable over single-photon excitation under many conditions because of lower matrix absorption and optical scattering of longer wavelength optical radiation. For example, FIGURE 2 shows the absorption and scattering properties for various components of animal tissue, such as human dermis, covering the ultraviolet (UV) to near infrared (NIR) spectral region.

Specifically, FIGURE 2 demonstrates how higher-energy photons 32 may experience considerably greater tissue absorption than lower-energy photons 34. For example, human skin strongly absorbs higher-energy photons 32 at 400 nm, but is relatively transparent to lower-energy photons 34 at 800 nm. This is a consequence of the natural absorbance of higher-energy photons 32 by blood, pigments, proteins, and genetic materials, among other natural components, of skin.

FIGURE 2 further demonstrates how higher-energy photons 42 may experience considerably greater tissue scatter than lower-energy photons 44. Any optically dense medium, such as human skin, will strongly scatter higher-energy photons 42, for example at 400 nm, but will exhibit much lower scatter for lower-energy photons 44 at 800 nm.

These differences in optical properties have two important consequences. First, absorption of short-wavelength, higher-energy photons 32 by tissue can result in undesirable tissue damage upon exposure to UV or other high-energy light. In contrast, negligible effects may be experienced upon illumination with lower-energy photons 34, such as NIR light, even when the optical power of the NIR light is many-fold higher than

that of the UV light. Secondly, the inherently high absorption and scatter of higher-energy photons 32 by tissue can result in very shallow tissue penetration depths, while lower-energy photons 34 generally have much greater penetration depths.

These important differences in absorption and penetration depth properties for higher-energy and lower-energy light are shown schematically in FIGURE 3. When UV light 50, for example light at 400 nm, impinges on human tissue 52, the majority of the optical energy is immediately absorbed and scattered in the outermost layers 54, such as the epidermis and dermis. Absorption may occur due to excitation of certain molecules in the cells of these outermost layers 54, such as those composing the genetic material in the cellular nucleus. This absorption of higher-energy light by cellular constituents can thereby initiate a variety of collateral photochemical changes 56 in these cells. These collateral photochemical changes 56 resulting from absorption of UV light 50 can include irreversible genetic damage and induction of cancer.

In contrast, NIR light 58, for example at 800 nm, will not be appreciably absorbed or scattered by tissue 52 or its outermost layers 54. The overall depth of penetration will be much greater, and the extent of collateral damage to cells will be substantially lower. Hence, if long-wavelength excitation light is used to replace the higher-energy light used for conventional single-photon excitation, it is possible to photoactivate specific molecules or pigments using relatively non-damaging, high penetration depth, simultaneous two-photon excitation.

Furthermore, the properties of simultaneous two-photon excitation have additional implications when coupled with the inherent non-damaging nature and low absorption of NIR light. For example, FIGURE 4 compares the extent of optically-induced damage in tissue when single-photon excitation 60 and simultaneous two-photon NIR excitation 62 methods are used to illuminate a subcutaneous tumor 64.

Single-photon excitation 60 produces a photoactivation zone 66 that extends substantially along the entire optical path and has no significant biospecificity. Hence, in addition to induction of the desired photoactivation in the tumor 64, collateral damage can occur throughout surrounding tissues, such as the dermis 68 and surrounding healthy tissue 70. If the single-photon excitation 60 is focussed, the photoactivation zone 66 will be slightly enhanced at the focus 72. This photoactivation zone 66, however, might not even extend into the tumor 64 if the UV or visible light is absorbed by the epidermis, dermis 68 or surrounding healthy tissue 70 prior to reaching the tumor 64. This can occur as a consequence of the inherently high absorptivity of tissue at short wavelengths.

In contrast, use of NIR light for simultaneous two-photon excitation 62 produces a sharply defined remote photoactivation zone 74 that is spatially localized at the focus 76 as a consequence of the non-linear properties of this excitation method. Such localization of activation in such a focal zone is a unique property of non-linear excitation processes, such as two-photon excitation. Furthermore, because tissue does not appreciably absorb NIR light, collateral damage to the surrounding dermis 68 and healthy tissue 70 is minimized.

Therapeutic applications of simultaneous two-photon excitation:

The foregoing discussion suggests that the fundamental differences in the absorption of UV and NIR light by tissue and cellular constituents, coupled with the special non-linear properties of simultaneous two-photon excitation, have direct applicability for improvements in various medical treatments, specifically in the modification or elimination of pigmented tissues.

Such simultaneous two-photon excitation enables improved localization in the photoactivation of photoactive agents with significantly reduced potential for collateral tissue damage compared with that possible using conventional methods.

Where control of penetration is not critical, non-focussed NIR light may be used to stimulate simultaneous two-photon photoactivation of agents present in a relatively large illuminated area. In such a case, the extent of agent photoactivation is controlled by varying the location, intensity and duration of exposure of such agents to the NIR beam.

Where precise control of penetration depth or volume extent of therapeutic application is more critical, focussed NIR light may be used to stimulate the simultaneous two-photon photoactivation process. In such a case, beam irradiance, exposure duration, and degree of focussing are used to control the extent of agent photoactivation.

In both cases, high-irradiance NIR light may be used to achieve maximum efficacy. Furthermore, the high penetration depths achievable with NIR light combined with the inherent localization of photoactivation that is possible with focused simultaneous two-photon excitation provide a means for photoactivating agents in subsurface tissues without damaging overlying or underlying healthy tissues.

Simultaneous Two-Photon Treatment with Endogenous Pigments

The method of the present invention improves on the above-described advantages through the use of simultaneous two-photon excitation to produce a therapeutic outcome based on photoactivation of endogenous pigments in order to treat pigmented tissues. "Endogenous" means pre-existing in a patient or target. "Pigments" means naturally occurring agents that absorb optical energy. Examples of such pigments include melanin, melanin precursors, carotenes, porphyrins (such as hemoglobin), various tattoo dyes and

other optically active species. "Therapeutic outcome" means photobleaching or photodynamic destruction of treated pigmented tissues resulting from the natural biological action of a photoactivated endogenous pigment. "Photobleaching" is the reduction or elimination of undesirable pigmentation, for example that caused by endogenous pigments present in moles, freckles, hair follicles and tattoos. "Photodynamic destruction" is localized tissue necrosis resulting from photochemical production of phototoxic products that destroy pigmented tissues, such as those pigmented tissues in pigmented tumors. Tissues suitable for treatment include pigmented tissues in which a specific therapeutic outcome is desired, such as moles, freckles, pigmented tumors, benign lesions, hair follicles and tattoos.

In a further embodiment of the present invention, a precursor to the endogenous pigments may be used. Examples of such precursors to pigments include 5-S-cysteinyldopa (5-SCD) and 5,6-dihydroxyindole (DHI), dopa, dopa semiquinone, leucodopachrome, dopachrome, eumelanins, pheomelanins, sepia melanins, and 5,6-dihydroxyindole-2-carboxylic acid. Such precursors have both photoprotective and phototoxic abilities. A metabolic precursor to melanin is a biochemical (e.g. 5-SCD, DHI) that is produced by the cell as part of the synthetic pathway that produces melanin. Melanin precursors, when activated by light, can generate phototoxic products that damage cellular materials (e.g., DNA) killing the target cells. Melanin precursors can be activated by two-photon excitation, as explained supra.

As also explained supra, melanin, melanin precursors, and other endogenous pigments are naturally occurring in human tissue, including in tumors. Such melanins, melanin precursors, or other endogenous pigments can be converted to phototoxic products after exposure to light.

The present invention uses the above-described simultaneous two-photon excitation to specifically target melanin, melanin precursors, or other endogenous pigments in pigmented tissues (such as melanomas and other tumors). The pigment is converted to a phototoxic product by NIR light upon simultaneous two-photon excitation.

5 The phototoxic product then causes damage to the pigmented tissues (by for example photobinding to cellular DNA or causing breaks in this DNA). This kills the cells in the pigmented tissues and, therefore, destroys it. Because simultaneous two-photon excitation is used to specifically target the melanin, melanin precursors, or other endogenous pigments only in the targeted tissue, any melanin, melanin precursors, or
10 other endogenous pigments in the tissue surrounding the targeted tissue are not converted to phototoxic products.

More specifically, use of simultaneous two-photon excitation produces a sharply defined focal zone that is substantially localized in depth and cross-section. This focal zone can be localized to the targeted tissue (such as a tumor) to be killed or a small zone
15 within or surrounding this tissue. As a result, photoactivation will only occur in the focal zone (i.e. in the tumor). Hence, any melanin, melanin precursors, or other endogenous pigment not in the targeted tissue, such as for example, in tissue surrounding a tumor, will not be photoactivated because it is outside the focal zone.

20 Additionally, as explained supra, the simultaneous two-photon excitation is able to penetrate deep into normal or cancerous tissue and photoactivate melanin or other endogenous pigments located deep within the tissue. As a result, tumors located deep within the body or large, deep tumors can be reached and destroyed. Destruction of these tumors can be done without activating melanin or other endogenous pigments along the path of the light or surrounding the tumor.

In addition to photodynamic destruction of pigmented tissues, such as those in pigmented tumors, the above-described unique features of simultaneous two-photon excitation may be used to achieve improved safety and specificity in the photobleaching of pigmented tissues, such as in moles, freckles, hair follicles and tattoos. The pigments present in such tissues can be activated by simultaneous two-photon activation, as explained supra, and upon activation may become photobleached. Thus, the present invention also uses simultaneous two-photon excitation to specifically target endogenous pigments in such pigmented tissues, thereby causing photobleaching and a desired reduction or elimination of apparent pigmentation.

It is a specific preferred embodiment of the present invention to employ the output of a NIR source, such as the mode-locked titanium:sapphire laser, to induce simultaneous two-photon photoactivation so as to photoactivate melanin, melanin precursors, or other endogenous pigments using light at a wavelength approximately twice that necessary for such conversion using conventional single-photon photoactivation. As explained supra, such NIR light exhibits improved penetration into tissue relative to that used for conventional single-photon photoactivation, and is less likely to produce collateral damage in tissues adjacent to the desired treatment target.

For the sake of simplicity and clarity, the following descriptions of preferred embodiments will focus on photodynamic destruction of pigmented tumor tissues, such as those in melanomas. However, it is important to note that the methods and apparatus described are equally applicable to the photobleaching of pigmented tissues, such as moles or tattoos, differing substantially only in the intended treatment target. In both classes of treatment, it is the photoactivation of the pigment that is fundamentally responsible for the desired therapeutic outcome.

Accordingly, a preferred embodiment is shown in FIGURE 5. The source 80 produces a beam of light 82 consisting of a rapid series of high peak power pulses of NIR light. For example, standard commercially available mode-locked titanium-sapphire lasers are capable of outputting mode-locked pulses with durations <200 fs and pulse energies of about 1-20 nJ at pulse repetition frequencies in excess of 75 MHz. This source produces a quasi-continuous beam of light having a relatively low average power (up to several Watts) but high peak power (on the order of 100 kW) that is continuously tunable over a NIR wavelength band from approximately 690-1080 nm. The pulse train from the source 80 constitutes a beam of light 82 that is easily focussed using standard optical means, such as reflective or refractive optics 84. The focused beam 86 can then be directed into a tumor 88 or other localized treatment target.

Simultaneous two-photon photoactivation of the melanin, melanin precursors, or other endogenous pigments will be substantially limited to the focal zone 90 of the focused light beam 86 due to the high instantaneous irradiance level that is only present at the focus. Furthermore, regardless of whether melanin, melanin precursors, or another endogenous pigment is present in surrounding healthy tissue 92 or skin 94, insignificant collateral photoactivation, photodamage or conversion into a phototoxic product will occur outside the focal zone 90. This is a consequence of the non-linear relationship between instantaneous optical power and simultaneous two-photon excitation, which limits significant excitation to the focal zone 90. Even if melanin, melanin precursors, or another endogenous pigment is present outside of the focal zone 90, excitation intensities are below that necessary to produce significant photoactivation.

The apparatus of the present invention can also include, for example, a focusing apparatus for focusing the light throughout a range of focal lengths extending from a surface of the tissue to a depth substantially beyond the surface. The source of light and

focusing apparatus cooperate to promote simultaneous two-photon excitation of the pigment at controllable locations throughout the volume of tissue.

By scanning the location of the focus of the beam 86 throughout the volume of the tumor 88, complete photoactivation of the melanin, melanin precursors, or other endogenous pigments into a phototoxic product throughout the tumor 88 can be effected. This scanning action can be produced by changing the position of the focus 86 relative to the tumor 88, or by moving the tumor 88 relative to a stationary focus 86 location. The quality of the focal region 90 of the focused light beam 86 may be improved by pre-expanding the light beam 82, using a beam expander or other device, prior to focusing using standard optical means.

This scanning can be done, for example, by positioning a focus of a beam of light over a range of positions so that a focal plane of the light beam occurs at a site located between a surface of the tissue and a point substantially beyond the tissue surface. As a result, treating the particular volume of tissue may extend to penetrate deep within the tissue. This scanning can further include varying, while the beam of light is extant, the radial position of the focal plane within the tissue, thereby to photoactivate the endogenous pigment at a multiplicity of positions between the tissue surface and a position located substantially beyond the tissue surface.

The simultaneous two-photon photoactivation embodiment of the present invention has several variations for the treatment of topical tissues, as shown in FIGURE 6 and in FIGURE 7. For example, the non-damaging nature of focused NIR light, shown in FIGURE 6, or of non-focused NIR light, shown in FIGURE 7, allows photoactivation of melanin or other endogenous pigments at topical locations without risk to underlying or surrounding tissues.

5 Focused simultaneous two-photon photoactivation of melanin or other endogenous pigments for topical therapy, as shown in FIGURE 6, is effected when a beam of light 82 from a source 80 is focused 86 onto a tumor 88 or other localized treatment target using standard optical means, such as reflective or refractive optics 84. In this manner, photoactivation of the melanin, melanin precursors, or other endogenous pigments into a phototoxic product occurs only at the focal zone 90. The surrounding healthy tissue 92 and skin 94 are unaffected in this process, even if they also contain melanin, melanin precursors, or another endogenous pigment, since photoactivation is substantially limited to the focal zone 90. As described previously, a scanning action can be used to effect photoactivation of the melanin, melanin precursor, or other endogenous pigment into a phototoxic product throughout the volume of the tumor 88.

10 Non-focused simultaneous two-photon photoactivation of melanin, melanin precursors, or other endogenous pigments for topical therapy, as shown in FIGURE 7, is effected when a non-focused or expanded beam of light 96 from a source 80 is directed onto a topical tumor 88 or other localized treatment target. This beam of light 96 may have a cross sectional area smaller than, equal to, or larger than that of the tumor 88. Since melanin, melanin precursors, or other endogenous pigments are present in substantially higher levels in the tumor 88, the therapeutic action will be substantially limited to the volume of the tumor 88. Since the beam of light 96 is non-damaging to tissues that do not contain a significant concentration of pigment, damage to surrounding healthy tissue 92 and skin 94 is avoided. This embodiment may be particularly useful when the exact location, size and shape of the tumor 88 are not known, or when it is otherwise undesirable to carefully control the location of application of the beam of light 96, since careful control of the location of the beam of light 96 is not critical for successful administration of this therapeutic regime. When non-focused light is used, employment

of extremely high peak power excitation sources, such as Q-switched lasers or regeneratively amplified mode-locked lasers, may be beneficial due to their exceptionally high peak radiant power (which is in the GW range) that will thereby afford a high instantaneous irradiance over a large area.

5 A final related variation of this preferred embodiment for simultaneous two-photon photoactivation is shown in FIGURE 8, where a non-focused or expanded beam of light 96 from a source 80 is directed onto a tumor 88 or other localized treatment target located below the skin's surface. This beam of light 96 may have a cross sectional area smaller than, equal to, or larger than that of the tumor 88. Since melanin, melanin precursors, or other endogenous pigments are present in substantially higher levels in a tumor 88, the therapeutic action will be substantially limited to the volume of the tumor 88. Since the beam of light 96 is non-damaging to tissues that do not contain a significant concentration of pigment, damage to surrounding healthy tissue 92 and skin 94 is avoided. This embodiment may also be particularly useful when the exact location, size and shape of the tumor 88 are not known, or when it is otherwise undesirable to carefully control the location of application of the beam of light 96, since careful control of the location of the beam of light 96 is not critical for successful administration of this therapeutic regime. As in the previous non-focused embodiment, employment of extremely high peak power excitation sources may be beneficial due to their exceptionally high peak radiant power and potential high instantaneous irradiance over a large area.

20 Preferably, the simultaneous two-photon excitation will be produced by an ultrashort pulsed NIR laser light having a wavelength of from approximately 450 nm to 1400 nm with a pulse width of from approximately 25 fs to 10 ns and a greater than approximately 1 kHz pulse repetition frequency. Such laser light can be produced by a mode-locked titanium:sapphire laser or related laser sources.

The extent and duration of excitation affected with such sources will be controlled by varying the location, irradiance and duration of application of the light.

The effectiveness of the therapeutic outcome may be markedly increased by simultaneous photoactivation and localized heating (hyperthermia) of the treatment site.

5 Such heating occurs as a secondary effect of illumination with laser light, and may also be controlled by varying the location, irradiance and duration of application of the light, so as to yield heating in the treatment zone of 2-10°C above normal temperatures. For example, application of light at intensities of 150-3000 mW/cm² may be used to produce such desirable hyperthermia. Alternately, secondary thermal sources, such as infrared
10 lamps or warm fluid baths, may be used to effect such desirable hyperthermia at the treatment site.

While the foregoing disclosure has primarily focused on example therapeutic applications using two-photon excitation of agents with ultrashort pulsed NIR light produced by mode-locked titanium:sapphire lasers, the present invention is not limited to
15 such excitation nor to such narrowly defined optical sources. In fact, aspects of the present invention are applicable when optical excitation is effected using linear or other non-linear methods. For example, various other optical sources are applicable, alone or in combination, such as continuous wave and pulsed lamps, diode light sources, semiconductor lasers; other types of gas, dye, and solid-state continuous, pulsed, or
20 mode-locked lasers, including: argon ion lasers; krypton ion lasers; helium-neon lasers; helium-cadmium lasers; ruby lasers; Nd:YAG, Nd:YLF, Nd:YAP, Nd:YVO₄, Nd:Glass, and Nd:CrGsGG lasers; Cr:LiSF lasers; Er:YAG lasers; F-center lasers; Ho:YAG and Ho:YLF lasers; copper vapor lasers; nitrogen lasers; optical parametric oscillators, amplifiers and generators; regeneratively amplified lasers; chirped-pulse amplified lasers;
25 and sunlight.

In an alternative embodiment, an exogenous photodynamic agent can be added to the patient to be activated in conjunction with the endogenous pigments. "Exogenous" agents are photoactive materials not pre-existent in a patient or other target which are for example administered for the purpose of increasing efficiency of conversion of optical energy into a therapeutic process. Examples of such exogenous agents include Rose Bengal, psoralen derivatives, indocyanine, Lutex, $\text{Sn}(\text{ET}_2)$ and various porphyrin derivatives, including porfimer sodium and benzoporphyrin derivative. Preferably, the targeted tissue is pretreated with the exogenous agent so that it retains a therapeutic concentration of the agent when the tissue is treated with light so as to promote simultaneous two-photon activation of the agent. Alternatively, the agent can be added at other times during the process. Upon administration and accumulation in targeted tissue, such agents can be used to efficiently interact with NIR light so as to kill tissue by Type I or Type II PDT mechanisms. Such killing can be used to augment or supplement killing of pigmented tissues using endogenous photoactive agents as described supra.

Another alternate embodiment of the present invention is directed to the thermal destruction of melanomas and other pigmented lesions.

Melanomas are usually dramatically darker than surrounding healthy tissue. The dark color associated with melanomas is caused by increased production of melanin by tumor cells. Melanin is a strong absorber of ultraviolet (UV) and visible light, and normally protects cells from the deleterious effects of solar UV radiation. For example, FIGURE 2 shows that melanin is highly absorptive at wavelengths shorter than approximately 1000 nm. In contrast, hemoglobin has minimal absorbance above 450 nm. The high concentration of melanin in most melanoma cells makes them capable of strongly and selectively absorbing light at wavelengths longer than 450 nm and shorter than 1000

nm. Thus, illumination of melanoma cells with light at such wavelengths will produce much more heat in those cells as compared to cells in less pigmented tissue.

Currently, laser illumination is used in cosmetic applications to remove unwanted hair. Laser hair removal is accomplished because there is more pigment in the hair follicles than in surrounding tissue. Therefore, when a laser illuminates the pigmented hair follicle, it absorbs much more of the light, causing localized heating. The localized hyperthermia thereby created in the bulb of the hair follicle kills the hair follicle while sparing surrounding tissue (which is not heated to a significant extent by the laser illumination).

The inventors of the present application have discovered a process to kill pigmented tumor cells by thermally overloading them whereas the relatively unpigmented cells in healthy tissues surrounding the tumor are spared. Figs. 9 and 10 illustrate such an alternate embodiment for the present invention wherein a focused light beam 86 (Fig. 9) and a non-focused light beam 96 (Fig. 10), respectively, are used to kill pigmented tumor cells 98. Such pigmented tumor cells 98 may be located at the surface of tissue 92 to be treated, or may be located significantly below the surface. Illumination of pigmented tumor cells 98 may be effected using a continuous wave or pulsed laser source operating in either of two wavelength bands between approximately 450 and 800 nm and between approximately 800 and 1400 nm.

For wavelengths between 450 and 800 nm, direct linear excitation of melanin is used to selectively promote thermal overload of pigmented tumor cells 98. Light in this band is preferred when pigmented tumor cells 98 are located at the surface of tissue or at depths of approximately 2 mm or less below the surface since such light is not capable of penetrating tissue to significantly greater depths. For such excitation, it is preferred that illumination be effected via application of one or more short pulses of light having a pulse

duration of 10 ns (nanoseconds) or less, and more preferably of 10 ps (picoseconds) or less. Use of such short duration pulses reduces thermal loss to surrounding tissues, thereby improving efficiency in selective thermal overload of the pigmented tumor cells 98. It is further preferred that the wavelength of this light be between approximately 600 and 800 nm to afford improved specificity for excitation of melanin relative to hemoglobin. Moreover, it is further preferred that such light be produced by a light source such as a mode-locked titanium:sapphire laser, which is readily able to deliver such light pulses at such wavelengths. A focused light beam 86 is preferable where the location and extent of the lesion is precisely known, since improved control over the extent of the treatment zone is thereby possible. By scanning this focused light beam 86 throughout the volume of the tumor, it is possible to treat the entirety of the pigmented tumor cells 98. However, where the location and extent of the lesion is not precisely known, or where the lesion is exceptionally large, use of a non-focused light beam 96 is preferred to assure that treatment is effected in all of the pigmented tumor cells 98.

For wavelengths between 800 and 1400 nm, excitation of melanin via linear mechanisms and non-linear two-photon mechanisms is used to selectively promote thermal overload of pigmented tumor cells 98. Light in this band is preferred when pigmented tumor cells 98 are located below the surface of tissue at depths of approximately 2 mm or greater since such light is capable of penetrating tissue to such depths. For such excitation, it is preferred that illumination be effected via application of one or more short pulses of light having a pulse duration of 10 ps or less, and more preferably of 1 ps or less. Use of such short duration pulses increases the efficiency of non-linear excitation mechanisms while simultaneously reducing thermal loss to surrounding tissues, thereby improving efficiency in selective thermal overload of the pigmented tumor cells 98. A focused light beam 86 is preferable where the location and extent of the lesion is precisely

known, since improved control over the extent of the treatment zone is thereby possible. Use of such a focused light beam 86 improves efficiency of non-linear excitation mechanisms, allowing relatively low energy light sources 80, such as mode-locked titanium:sapphire lasers, to be successfully used. By scanning this focused light beam 86 throughout the volume of the tumor it is possible to treat the entirety of the pigmented tumor cells 98. However, where the location and extent of the lesion is not precisely known, or where the lesion is exceptionally large, use of a non-focused light beam 96 is preferred to assure that treatment is effected in all of the pigmented tumor cells 98. Under such illumination conditions, amplified or other higher energy light sources 80, such as the regeneratively amplified mode-locked titanium:sapphire laser, are preferred so as to increase illumination intensities to levels sufficient to achieve efficient non-linear excitation.

It will be clear that the methods and apparatus described for this alternate embodiment will be equally applicable to the treatment of other pigmented blemishes, such as for example moles, port wine stains, freckles, scars, and tattoos, and for the reduction or elimination of pigments in hair.

While the present invention has been illustrated and described as embodied in general methods and apparatus for killing pigmented tumors by activation of endogenous pigments using optical radiation, it is not intended to be limited to the details shown, since it will be understood that various omissions, modifications, substitutions and changes in the forms and details of the method illustrated and in its operation can be made by those skilled in the art without departing in any way from the spirit of the present invention.

This description has been offered for illustrative purposes only and is not intended to limit the invention of this application, which is defined in the claims below.

What is claimed as new and desired to be protected by Letters Patent is set forth in the appended claims.

We claim:

Claim 1. A method for the treatment of a particular volume of tissue, said volume of tissue containing an endogenous pigment, the method comprising the steps of:
treating the particular volume of tissue with light to promote a simultaneous two-photon photoactivation of said pigment in the particular volume of tissue, wherein the pigment becomes photochemically activated in the particular volume of tissue.

Claim 2. The method of Claim 1 wherein the light to promote said simultaneous two-photon photoactivation is a laser light produced by a laser.

Claim 3. The method of Claim 2 wherein the laser light comprises a train of one or more ultrashort pulses.

Claim 4. The method of Claim 2 including operating the laser to produce light at a wavelength between approximately 450 nm to 1400 nm.

Claim 5. The method of Claim 1 wherein the light to promote said simultaneous two-photon photoactivation is a focused beam of light.

Claim 6. The method of Claim 5 wherein the focused beam of light is focused laser light.

Claim 7. The method of Claim 6 wherein said particular volume of tissue is located substantially at the tissue surface.

Claim 8. The method of Claim 6 wherein said particular volume of tissue is located substantially below the tissue surface.

5 Claim 9. The method of Claim 1 wherein said step of treating the particular volume of tissue includes positioning a focus of a beam of light over a range of positions so that a focal plane of the light beam occurs at a site located between a surface of the tissue and a point substantially beyond the tissue surface, whereby said step of treating the particular volume of tissue may extend to penetrate deep within the tissue.

10 Claim 10. The method of Claim 9 further including varying, while the beam of light is extant, the radial position of the focal plane within the tissue, thereby to photoactivate the endogenous pigment at a multiplicity of positions between the tissue surface and a position located substantially beyond the tissue surface.

15 Claim 11. The method of Claim 1 wherein said endogenous pigment becomes photoactivated in said particular volume at a controllable position substantially beyond a tissue surface.

20 Claim 12. The method of Claim 1 further comprising the step of controlling the photoactivation by varying the location, irradiance and duration of said light.

Claim 13. The method of Claim 1 wherein the light to promote said simultaneous two-photon excitation of the endogenous pigment is a non-focused beam of light.

Claim 14. The method of Claim 13 wherein said particular volume of tissue is located substantially at the tissue surface.

5 Claim 15. The method of Claim 13 wherein said particular volume of tissue is located substantially below the tissue surface.

10 Claim 16. The method of Claim 1 wherein said endogenous pigment is selected from the group comprising melanin, melanin precursors, carotenes, porphyrins, and various tattoo dyes.

15 Claim 17. The method of Claim 16 wherein said melanin precursors are selected from the group comprising 5-S-cysteinyl-dopa (5-SCD) and 5,6-dihydroxyindole (DHI), dopa, dopa semiquinone, leucodopachrome, dopachrome, eumelanins, pheomelanins, sepia melanins, and 5,6-dihydroxyindole-2-carboxylic acid.

20 Claim 18. The method of Claim 16 wherein said porphyrins include hemoglobin.

25 Claim 19. A method for producing a photoactivated product in a particular volume of a material, the method comprising treating the particular volume of the material with light to promote a simultaneous two-photon excitation of an endogenous pigment contained in the particular volume of the material, wherein the pigment becomes a photoactivated product in the particular volume of the material.

30 Claim 20. The method of Claim 19 wherein the light to promote said simultaneous two-photon photoactivation is a laser light produced by a laser.

Claim 21. The method of Claim 20 wherein the laser light comprises a train of one or more ultrashort pulses.

Claim 22. The method of Claim 20 including operating the laser to produce light at a wavelength between approximately 450 nm to 1400 nm.

Claim 23. The method of Claim 19 wherein the light to promote said simultaneous two-photon photoactivation is a focused beam of light.

Claim 24. The method of Claim 23 wherein the focused beam of light is focused laser light.

Claim 25. The method of Claim 24 wherein said particular volume of material is tissue located substantially at the surface of said material.

Claim 26. The method of Claim 24 wherein said particular volume of material is tissue located substantially below the surface of said material.

Claim 27. The method of Claim 19 wherein said step of treating the particular volume of material includes positioning a focus of a beam of light over a range of positions so that a focal plane of the light beam occurs at a site located between a surface of the material and a point substantially beyond the material surface, whereby said step of treating the particular volume of material may extend to penetrate deep within the material.

Claim 28. The method of Claim 27 further including varying, while the beam of light is extant, the radial position of the focal plane within the material, thereby to photoactivate the endogenous pigment at a multiplicity of positions between the material surface and a position located substantially beyond the material surface.

5

Claim 29. The method of Claim 19 wherein said endogenous pigment becomes photoactivated in said particular volume at a controllable position substantially beyond a material surface.

10

Claim 30. The method of Claim 19 further comprising the step of controlling the photoactivation by varying the location, irradiance and duration of said light.

15

Claim 31. The method of Claim 19 wherein the light to promote said simultaneous two-photon excitation of the endogenous pigment is a non-focused beam of light.

20

Claim 32. The method of Claim 31 wherein said particular volume of material is located substantially at the surface of said material.

Claim 33. The method of Claim 31 wherein said particular volume of material is tissue located substantially below the surface of said material.

25

Claim 34. The method of Claim 19 wherein said endogenous pigment is selected from the group comprising melanin, melanin precursors, carotenes, porphyrins, and various tattoo dyes.

Claim 35. The method of Claim 34 wherein said melanin precursors are selected from the group comprising 5-S-cysteinyl-dopa (5-SCD) and 5,6-dihydroxyindole (DHI), dopa, dopa semiquinone, leucodopachrome, dopachrome, eumalanins, pheomelanins, sepia melanins, and 5,6-dihydroxyindole-2-carboxylic acid.

5

Claim 36. The method of Claim 34 wherein said porphyrins include hemoglobin.

Claim 37. A method for treatment of tissue wherein the tissue includes an endogenous pigment, the method comprising the steps of:

10 directing light to specific regions of interest within the tissue, including regions substantially below a tissue surface, said light being selected to penetrate the tissue and to promote two-photon excitation substantially only at a focal zone;

controlling the location of said focal zone over a range of depths within said tissue;
and

15 using two-photon excitation, photoactivating said pigment over said range of depths within said tissue, thereby producing a photoactivated product substantially only at the focal zone.

Claim 38. The method of Claim 37 wherein said directing step includes
20 directing a laser light produced by a laser to said regions of interest.

Claim 39. The method of Claim 38 wherein the laser light comprises a train of one or more ultrashort pulses.

Claim 40. The method of Claim 38 including operating the laser to produce light at a wavelength between approximately 450 nm to 1400 nm.

5 Claim 41. The method of Claim 37 wherein the light to promote said two-photon photoactivation is a focused beam of light.

Claim 42. The method of Claim 41 wherein the focused beam of light is focused laser light.

10 Claim 43. The method of Claim 42 wherein said regions of interest are located substantially at the tissue surface.

Claim 44. The method of Claim 42 wherein said regions of interest are located substantially below the tissue surface.

15 Claim 45. The method of Claim 42 further comprising the step of scanning said regions of interest with said focused beam of light to promote two-photon excitation throughout said regions of interest.

20 Claim 46. The method of Claim 37 wherein said endogenous pigment becomes photoactivated in said focal zone at a controllable position substantially beyond a tissue surface.

25 Claim 47. The method of Claim 37 wherein said two-photon photoactivation is simultaneous two-photon activation.

Claim 48. The method of Claim 37 further comprising the step of controlling the photoactivation by varying the location, irradiance and duration of said light.

Claim 49. The method of Claim 37 wherein the light to promote said two-photon excitation of the photoactive agent is a non-focused beam of light.

Claim 50. The method of Claim 49 wherein said regions of interest are located substantially at the tissue surface.

Claim 51. The method of Claim 49 wherein said regions of interest are located substantially below the tissue surface.

Claim 52. The method of Claim 37 wherein said endogenous pigment is selected from the group comprising melanin, melanin precursors, carotenes, porphyrins, and various tattoo dyes.

Claim 53. The method of Claim 52 wherein said melanin precursors are selected from the group comprising 5-S-cysteinyl-dopa (5-SCD) and 5,6-dihydroxyindole (DHI), dopa, dopa semiquinone, leucodopachrome, dopachrome, eumalanins, pheomelanins, sepia melanins, and 5,6-dihydroxyindole-2-carboxylic acid.

Claim 54. The method of Claim 52 wherein said porphyrins include hemoglobin.

Claim 55. A method for the treatment of a particular volume of tissue, said volume of tissue containing an endogenous pigment, the method comprising the steps of:

treating the particular volume of tissue with light to promote thermal overload of pigmented cells in the particular volume of tissue, wherein said thermal overload kills said pigmented cells.

5 Claim 56. The method of Claim 55 wherein the light to promote said thermal overload is a laser light produced by a laser.

Claim 57. The method of Claim 56 wherein the laser light comprises a train of one or more ultrashort pulses.

10 Claim 58. The method of Claim 56 including operating the laser to produce light at a wavelength between approximately 450 nm to 800 nm.

Claim 59. The method of Claim 58 wherein said wavelength of light is between
15 approximately 600 nm and 800 nm.

Claim 60. The method of Claim 58 wherein said particular volume of tissue is located substantially at the tissue surface.

20 Claim 61. The method of Claim 58 wherein said particular volume of tissue is located approximately 2 mm or less below the tissue surface.

Claim 62. The method of Claim 58 wherein said laser light has a pulse duration of less than 10 ns.

Claim 63. The method of Claim 62 wherein said laser light has a pulse duration of less than 10 ps.

Claim 64. The method of Claim 56 including operating the laser to produce light at a wavelength between approximately 800 nm to 1400 nm.

Claim 65. The method of Claim 64 wherein said particular volume of tissue is located approximately 2 mm or greater below the tissue surface.

Claim 66. The method of Claim 64 wherein said laser light has a pulse duration of less than 10 ps.

Claim 67. The method of Claim 66 wherein said laser light has a pulse duration of less than 1 ps.

Claim 68. The method of Claim 55 wherein the light to promote said thermal overload is a focused beam of light.

Claim 69. The method of Claim 68 wherein the focused beam of light is focused laser light.

Claim 70. The method of Claim 68 wherein said step of treating the particular volume of tissue includes scanning said particular volume of tissue with said focused beam of light so as to promote thermal overload throughout said particular volume of tissue.

Claim 71. The method of Claim 55 wherein the light to promote said thermal overload is a non-focused beam of light.

Claim 72. The method of Claim 55 wherein said endogenous pigment is selected from the group comprising melanin, melanin precursors, carotenes, porphyrins, and various tattoo dyes.

Claim 73. The method of Claim 72 wherein said melanin precursors are selected from the group comprising 5-S-cysteinyl-dopa (5-SCD) and 5,6-dihydroxyindole (DHI), dopa, dopa semiquinone, leucodopachrome, dopachrome, eumelanins, pheomelanins, sepia melanins, and 5,6-dihydroxyindole-2-carboxylic acid.

Claim 74. The method of Claim 72 wherein said porphyrins include hemoglobin.

Claim 75. A method for treatment of a particular volume of tissue, said volume of tissue containing an endogenous pigment and an exogenous photodynamic agent, the method comprising the steps of:

treating the particular volume of tissue with light to promote a simultaneous two-photon photoactivation of said pigment and said agent in said particular volume of tissue, wherein the pigment becomes photochemically converted into a phototoxic product in the particular volume of tissue and said photodynamic agent becomes photoactivated in the particular volume of tissue.

Claim 76. The method of Claim 75 wherein said exogenous photodynamic agent is selected from the group comprising Rose Bengal, psoralen derivatives, indocyanine,

Lutex, Sn(ET)_2 , and various porphyrin derivatives, including porfimer sodium and benzoporphyrin derivative.

5 Claim 77. The method of Claim 75 wherein the particular volume of tissue is pretreated with said exogenous photodynamic agent such that the particular volume of tissue retains a portion of said agent at the time the particular volume of tissue is treated with light so as to promote simultaneous two-photon activation of said agent.

10 Claim 78. Apparatus for treating a particular volume of tissue containing an endogenous pigment, the apparatus comprising:

15 a source of light and light delivery apparatus for directing light at and into said particular volume of tissue, said light being selected in frequency and energy to promote simultaneous two-photon excitation of said endogenous pigment so that said pigment becomes photochemically activated in said particular volume of tissue.

20 Claim 79. The apparatus of Claim 78 wherein said endogenous pigment is selected from the group comprising melanin, melanin precursors, carotenes, porphyrins, and various tattoo dyes.

25 Claim 80. The apparatus of Claim 79 wherein said melanin precursors are selected from the group comprising 5-S-cysteinyldopa (5-SCD) and 5,6-dihydroxyindole (DHI), dopa, dopa semiquinone, leucodopachrome, dopachrome, eumalanins, pheomelanins, sepia melanins, and 5,6-dihydroxyindole-2-carboxylic acid.

30 Claim 81. The apparatus of Claim 79 wherein said porphyrins include hemoglobin.

Claim 82. The apparatus of Claim 79 wherein said source of light is a laser light produced by a laser.

5 Claim 83. The apparatus of Claim 82 wherein said laser light comprises a train of one or more ultrashort pulses.

Claim 84. The apparatus of Claim 82 wherein said laser light has a wavelength between approximately 450 nm to 1400 nm.

10 Claim 85. The apparatus of Claim 78 wherein said particular volume of tissue is located substantially at the tissue surface.

Claim 86. The apparatus of Claim 78 wherein said particular volume of tissue is located substantially below the tissue surface.

15 Claim 87. The apparatus of Claim 78 wherein said light is non-focused light.

20 Claim 88. The apparatus of Claim 78 further comprising a focusing apparatus for focusing the light throughout a range of focal lengths extending from a surface of said tissue to a depth substantially beyond said surface, said source of light and focusing apparatus cooperating to promote simultaneous two-photon excitation of said pigment.

Claim 89. The apparatus of Claim 78 further comprising an exogenous photodynamic agent in said particular volume of tissue, said light being selected in

frequency and energy to promote simultaneous two-photon activation of said agent so that said agent becomes photoactivated in the particular volume of tissue.

5 Claim 90. The apparatus of Claim 89 wherein said exogenous photodynamic agent is selected from the group comprising Rose Bengal, psoralean, indocyanine, Lutex, Sn(ET)₂ and various porphyrin derivatives, including porfimer sodium and benzoporphyrin derivative.

10 Claim 91. An apparatus for treating a particular volume of tissue containing an endogenous pigment, the apparatus comprising:

 a source of light and light delivery apparatus for directing light at and into said particular volume of tissue, said light being selected to promote thermal overload of pigmented cells in the particular volume of tissue, wherein said thermal overload kills said pigmented cells.

15 Claim 92. The apparatus of Claim 91 wherein said source of light is a laser light produced by a laser.

20 Claim 93. The apparatus of Claim 92 wherein said laser light comprises a train of one or more ultrashort pulses.

Claim 94. The apparatus of Claim 92 wherein said laser light has a wavelength between approximately 450 nm to 1400 nm.

Claim 95. The apparatus of Claim 91 wherein said particular volume of tissue is located substantially at the tissue surface.

5 Claim 96. The apparatus of Claim 91 wherein said particular volume of tissue is located substantially below the tissue surface.

10 Claim 97. The method of Claim 1 further comprising the step of heating said volume of tissue using said light so to produce a hyperthermic effect and controlling the hyperthermic effect by varying the location, irradiance and duration of said light so as to augment the effectiveness of said photoactivation.

15 Claim 98. The method of Claim 19 further comprising the step of heating said volume of material using said light so to produce a hyperthermic effect and controlling the hyperthermic effect by varying the location, irradiance and duration of said light so as to augment the effectiveness of said photoactivation.

Claim 99. The method of Claim 1 wherein said photochemical activation of said pigment includes conversion of said pigment into a phototoxic product.

20 Claim 100. The method of Claim 1 wherein said photochemical activation of said pigment includes photobleaching of the pigment in said tissue.

Claim 101. The method of Claim 100 wherein said tissue is selected from the group comprising moles, freckles, hair follicles and tattoos.

Claim 102. The method of Claim 19 wherein said photoactivated product is a phototoxic product.

5 Claim 103. The method of Claim 19 wherein said photoactivation of said pigment includes photobleaching of the pigment in said material.

Claim 104. The method of Claim 103 wherein said material is selected from the group comprising moles, freckles, hair follicles and tattoos.

10 Claim 105. The method of Claim 37 wherein said photoactive product is a phototoxic product.

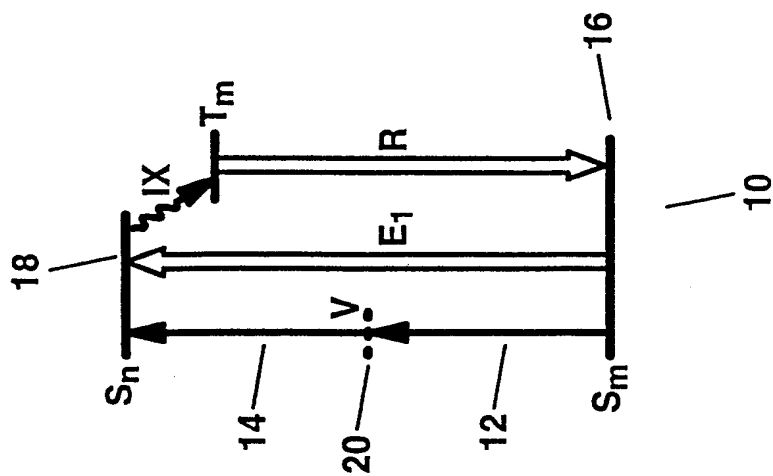
Claim 106. The method of Claim 37 wherein said photoactivating of said pigment includes photobleaching of said pigment in said tissue.

15 Claim 107. The method of Claim 106 wherein said tissue is selected from the group comprising moles, freckles, hair follicles and tattoos.

20 Claim 108. the apparatus of Claim 78 wherein said photochemical activation of said pigment includes conversion of said pigment into a phototoxic product.

Claim 109. The apparatus of Claim 78 wherein said photochemical activation of said pigment includes photobleaching of the pigment in said tissue.

Claim 110. The apparatus of Claim 109 wherein said tissue is selected from the group comprising moles, freckles, hair follicles, and tattoos.

Fig. 1.

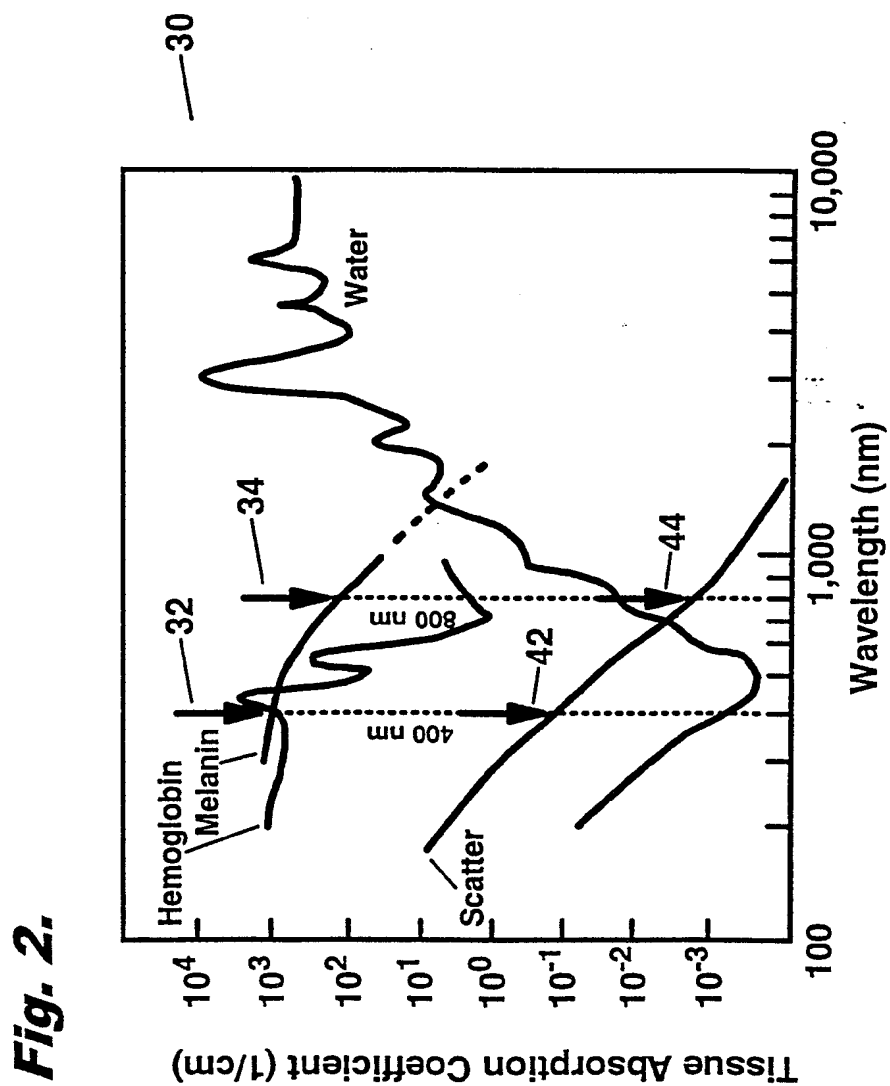


Fig. 3.

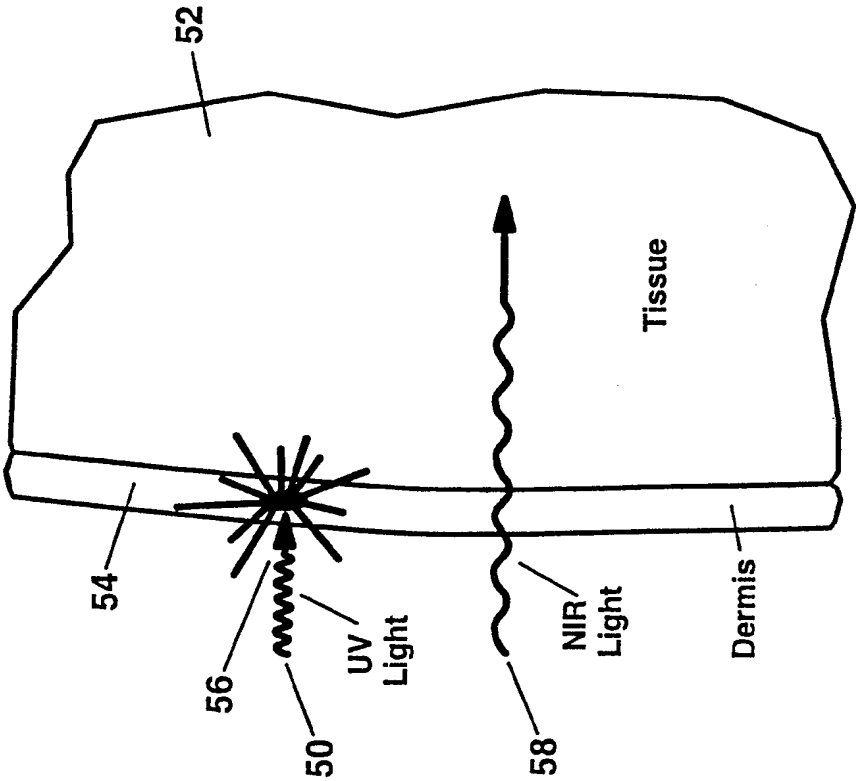
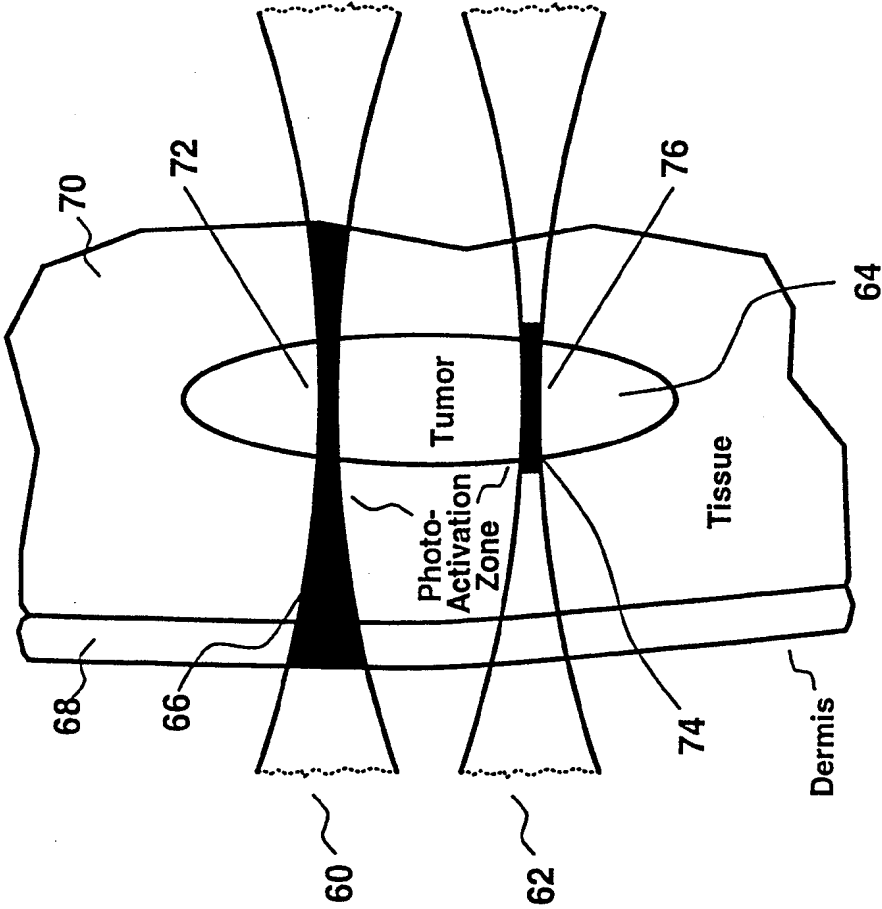


Fig. 4.



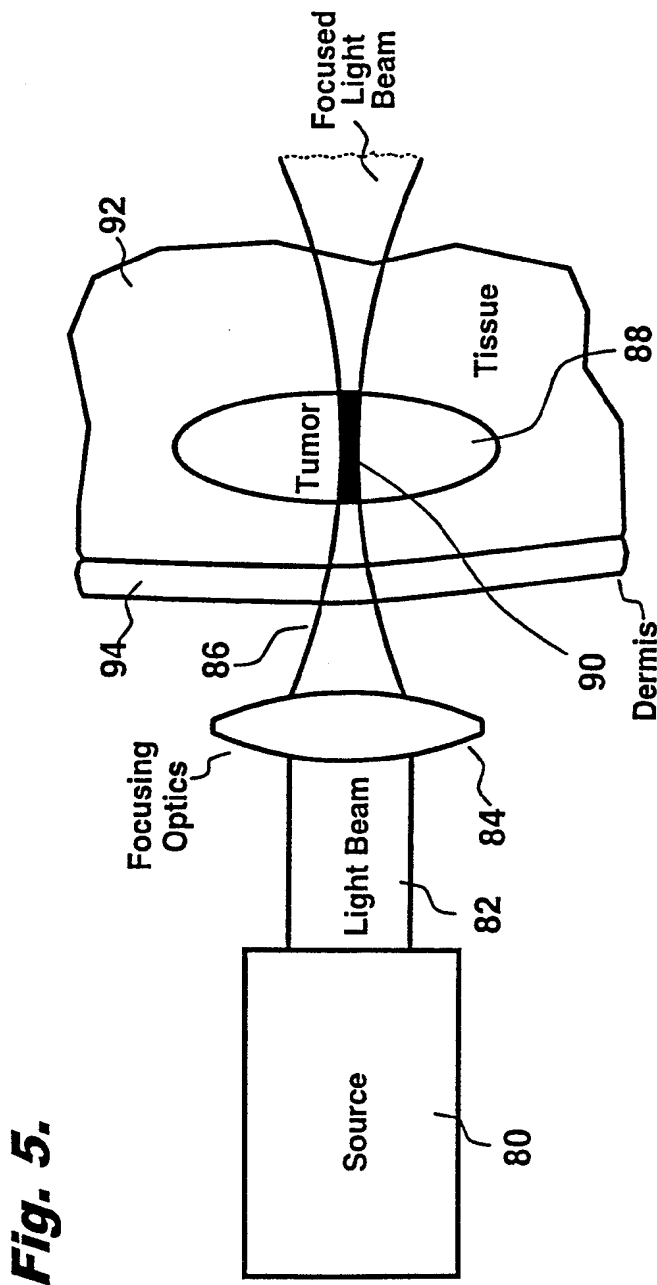


Fig. 6.

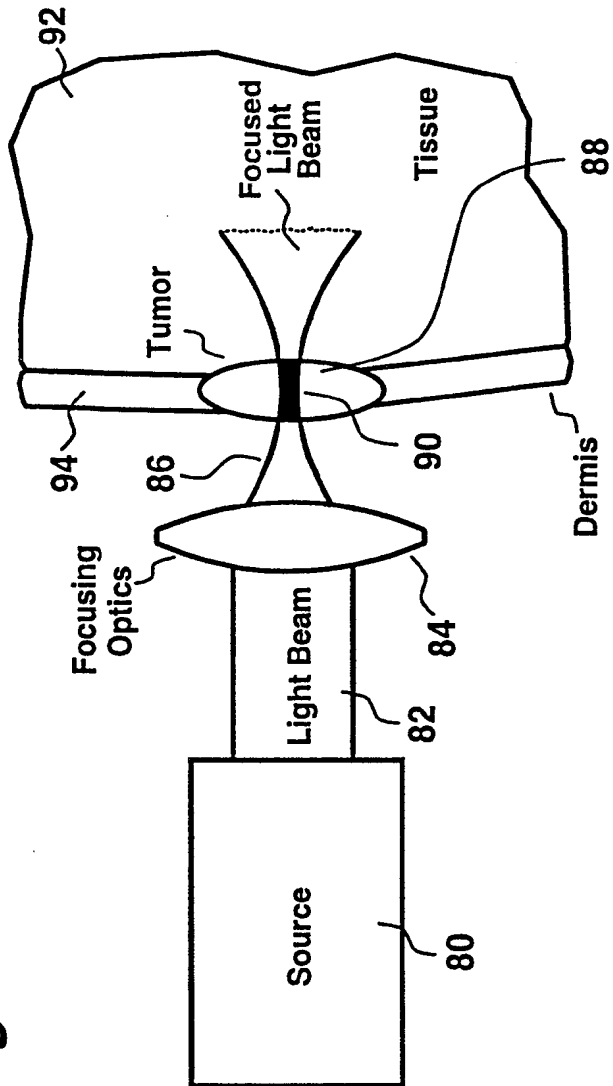


Fig. 7.

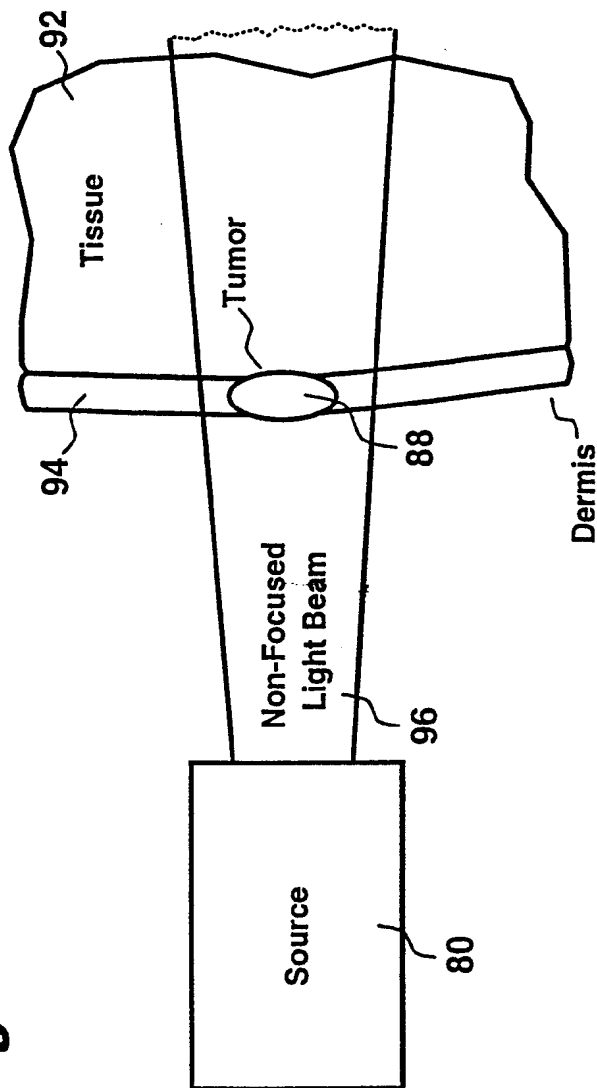


Fig. 8.

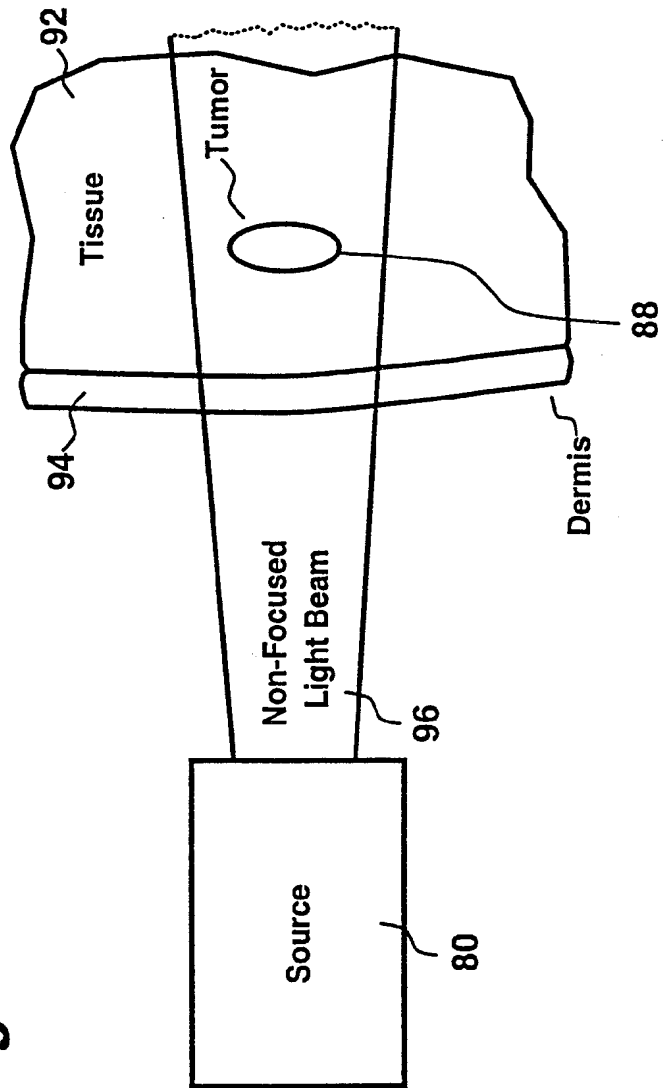


Fig. 9.

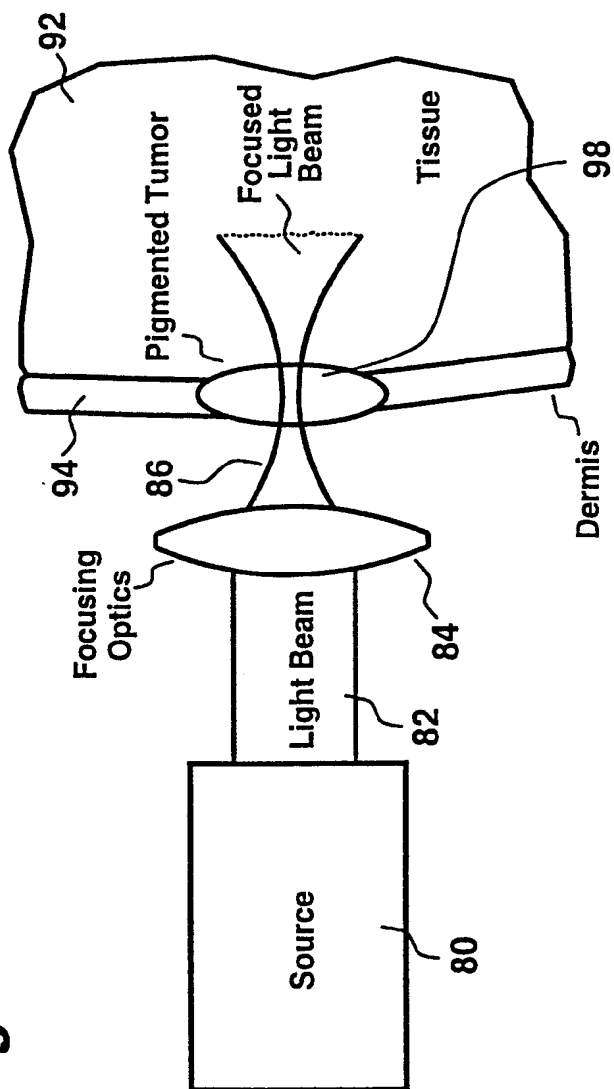
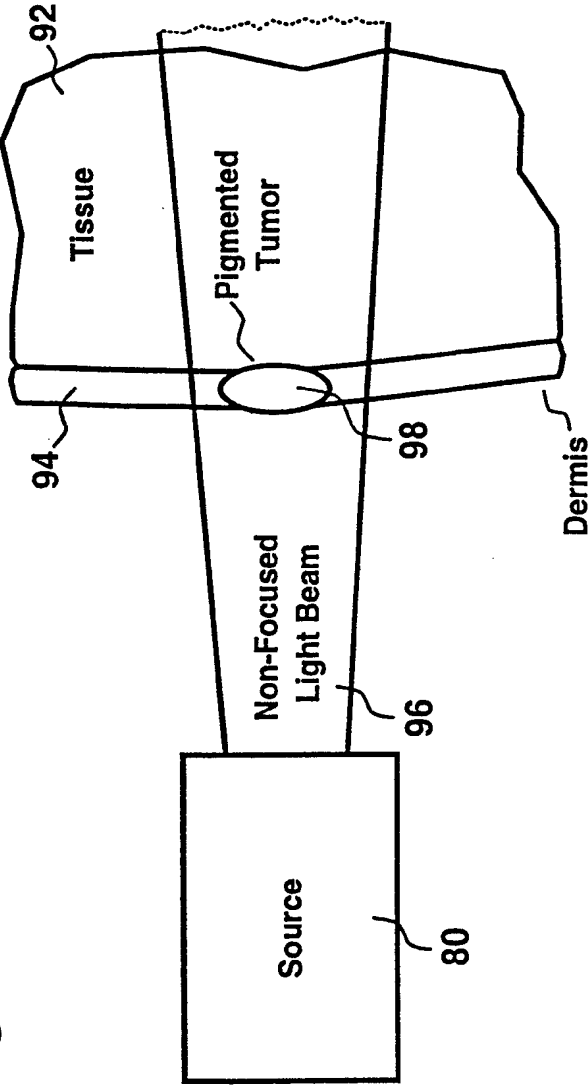


Fig. 10.



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/17176

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :A61B 19/00

US CL :128/898

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 128/898; 250/458.1; 604/20; 606/9; 607/2, 3, 89

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WEST, EAST, MEDLINE, APS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	US 5,829, 448 A (FISHER et al.) 03 November 1998, entire document.	1-110
A	US 4,822,335 A (KAWAI et al.) 18 April 1989, entire document.	78-96, 108-110
A	US 5,034,613 A (DENK et al.) 23 July 1991, entire document.	19-36, 78-96, 98, 102-104, 108-110
A	STABLES et al., Photodynamic therapy, Antitumour Treatment, Cancer Treatment Reviews (1995) 21, pages 311-323.	1-77, 97-107

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
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Date of the actual completion of the international search
25 OCTOBER 1999

Date of mailing of the international search report

18 NOV 1999

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US99/17176

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	KATSUMI et al., Photodynamic Therapy with a Diode Laser for Implanted Fibrosarcoma in Mice Employing Mono-L-Aspartyl Chlorin E6 , Research Note, Photochemistry and Photobiology, 1996. 64(4), pages 671-675.	1-110



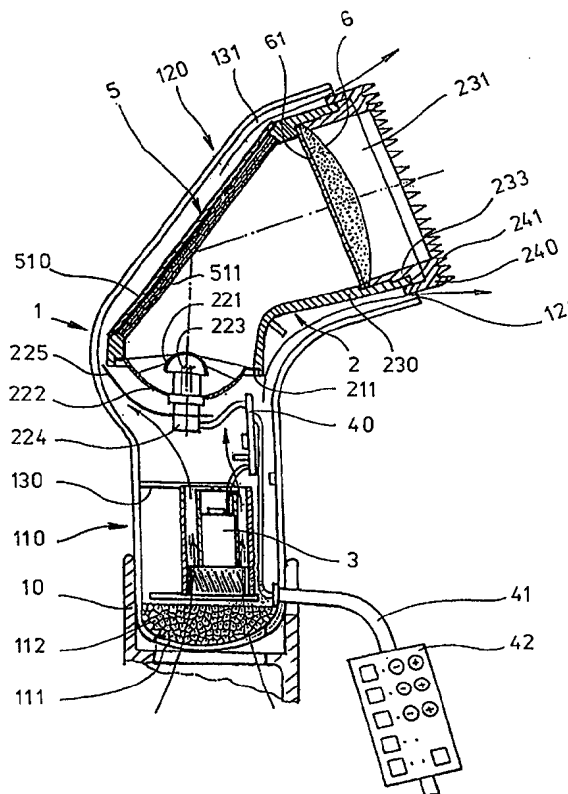
INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(21) International Application Number: PCT/CZ99/00044 (22) International Filing Date: 24 November 1999 (24.11.99) (30) Priority Data: PV 3823-98 24 November 1998 (24.11.98) CZ PUV 10058-99 9 November 1999 (09.11.99) CZ (71)(72) Applicant and Inventor: VOVES, Vladimir [CZ/CZ]; Lukavec 268, 395 26 Lukavec (CZ). (72) Inventor; and (75) Inventor/Applicant (for US only): PICKA, Pavel [CZ/CZ]; Myslíkova 70, 395 01 Pacov (CZ). (74) Agent: FISCHER, Michael; Na Hrobcí 5, 128 00 Praha 2 (CZ).			(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE). Published <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i> <i>In English translation (filed in Czech).</i>

(54) Title: INSTRUMENT FOR LIGHT THERAPY

(57) Abstract

The instrument for light therapy consists of an outer casing (1) with a front section (120) terminated with the first hole (121), in which inner casing (2) with a light source (223), reflector (221, 222) and Brewster polariser (5) consisting of a system parallel glass plates (511) lying on each other are located, while the output section (230) of the inner casing (2) reaching as far as the first hole (121) of the outer casing (1) holds a light filter (112), and with a rear section (110) that changes into the second hole (111), in which fan (3) for generation of pressure difference between both holes (121, 111) is located, whereas the system of glass plates (511) of Brewster polariser (5) consists of drawn glass plates (511) with surface irregularities defining cavities (512) of unequal shape between plates (511). A massage ring (240) is allocated to the Brewster polariser, that is located in output section (230) of inner casing (2) and/or at the end of front part (120) of outer casing (1).



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Instrument for Light Therapy

Description

The invention concerns an instrument for light therapy, consisting of an outer casing with a front section terminated with the first hole, in which inner casing with a light source, reflector and Brewster polariser consisting of a system parallel glass plates lying on each other are located, while the output section of the inner casing reaching as far as the first hole of the outer casing holds a light filter, and with a rear section that changes into the second hole, in which fan for generation of pressure difference between both holes is located.

Instruments for light therapy are used to support biological processes by means of effects of linear-polarised light. Action of the linear-polarised light increases cell activity and supports healing processes of various disturbances of body surface such as wounds, furuncles and various disturbances of epithelium. In the publication DE 3220218 an equipment and a method are described for a stimulation of biological processes and for activating cells by means of linear-polarised light. The Brewster polariser consists of a larger number of plane-parallel glass plates from common transparent glass inclined under the known Brewster angle, e.g. four glass plates with a double number of reflection planes that reflect about 35% of incident light. The Brewster polariser is placed in a cylindrical cabinet with the same diameter as the reflector and lens body. The cylindrical cabinet is cut in the axis with an inclined plane and glass plates are inserted into the ellipse-shaped cross-

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section. Rays pass through under an obtuse angle that corresponds to the double of the Brewster angle. The linear-polarised light has continuous or seemingly continuous distribution of spectrum in the usable direction. Despite the indisputable healing effects, the bundle of rays generated by the light source generates too much heat at higher power output that in case of the current configuration cannot be satisfactorily removed by means of air from fan. Another disadvantage of this appliance is a complicated construction of the optical equipment. The publication WO 96/04958 describes a healing lamp with a Brewster polariser formed by several drawn glass plates lying directly one on the other. These glass plates provide better heat removal thanks to a close contact of glass plates and thanks to cooling air passing through a narrow gap between the casing jacket and system of glass plates of the Brewster polariser. Because the light space with reflector, light source, glass plates of the Brewster polariser and output filter is separated from the space, through which air passes, and because flowing air has no access between glass plates of the Brewster polariser, the polariser is not polluted with dust. The cooling air passes through the casing of the instrument and leaves the casing in a different direction than to the cured area. The disadvantage of this configuration is a complicated manufacture of the whole instrument, low efficiency of light reflection and impossibility to use the airflow to support the instrument's healing effect. The publication DE 3733905 describes a healing lamp with linear-polarised light. With this lamp, the reflector with a light source generates a bundle of rays that impinges on the Brewster polariser made of a larger number of plane-parallel glass plates configured next to each other at small determined distances. Glass plates are enclosed in a

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metal plate, whose outer surface is fitted with cooling fins as well as the outer surface of the reflector. The healing lamp consists of two tubular casings that make an angle that corresponds to the Brewster angle. The Brewster polariser is located in the cranked section. The straight section is tightly closed by means of a filtration insert. The disadvantage of the above-described healing lamp is its robust construction necessary to achieve a satisfactory light performance. Documentation EP 0137005 describes a healing illumination instrument consisting of a crank-shaped cylindrical casing, whose cranked section accommodates the Brewster polariser plates. One of the straight sections of the casing holds a light source with reflector, which transmits a bundle of rays onto the Brewster polariser plates. The bundle of rays reflects from these plates into the second straight section of the casing and the light beam leaves the instrument at the output hole of the second straight section. This hole is arranged around an optical appliance, which can be, for example, an optical filter. A fan is located after the reflector in the first straight section of the casing. This fan causes air to be sucked from the output hole area into the second straight section, the air passes through the cranked section of the cylindrical casing and a peripheral gap along the reflector into the fan that forces the air out from the casing through holes in the facing wall of the first straight section. The fan can be set to the opposite direction of airflow, in which case the air is sucked in through holes in the facing wall of the first straight section, passes through the fan and is pushed through an annular gap between the reflector and casing. Then the air flows along the top plate of the Brewster polariser and after changing the direction in the cranked section of the casing, the air flows through the

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second straight section through annular holes along the optical equipment out of the instrument. In case of the latter direction of flow, the air flows to the healed area and around. However, disadvantage of this instrument is that in case of this direction, the air flows directly along the top plate of the Brewster polariser and hits the optical equipment located in the output hole of the second section and pollutes it with dust. Documentation WO 96/04959 describes a healing lamp for generation of linear-polarised light that consists of an outer casing with a shape of cranked cylinder with holes on both sides, and of an inner casing located inside the outer casing. The inner casing also has a shape of a cranked cylinder. One end of the inner casing is fitted with a reflector with a light source transmitting a bundle of rays onto plates of the Brewster polariser located at the area of cranking of the cylindrical shape of the inner casing. The bundle reflects from the plates of the Brewster polariser and leaves the instrument through the output hole in the output section of the inner casing that terminates at the area of the outer casing output hole. An annular gap is formed between the output section of the inner casing and the first input hole of the outer casing. The fan located in the area of the second output hole of the outer casing sucks air that passes through this gap into the inner area of the outer casing. The fan forces the sucked air out of the outer casing through the second output hole. The air flows in the direction from the healed area, through the annular gap between the output section of the inner casing and the first output hole of the outer casing along the reflector and further along the inner electrical wiring into the fan and from the fan through the hole in the outer casing into the environment, which seems to be disadvantageous, because the flowing air is not utilised to

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increase the healing effects. The sucked air simultaneously carries a mass of biological contamination from the healed area into the annular gap between the output section of the inner casing and the first input hole of the outer casing. This biological contamination is undesirably deposited on the inner wiring of the instrument. This effect is undesirable, because this is a biological contamination, which is a source of various infections. Disadvantage of this healing lamp according to the above description also is a limited light performance and a limited healing effect. The limited light performance and healing effect are caused by low efficiency of light reflection on the Brewster polariser. The Brewster polariser according to the above description consists of several layers of drawn glass plates arranged directly on top of each other. Purchase costs of floated glass plates are high. The reflection efficiency of bundle of rays on the above glass plates is low and therefore also the light performance of the bundle of rays, that flows out from the output hole of the output section of the inner casing onto the healed area, is low. The low reflection efficiency of the light bundle on the glass plates of the Brewster polariser is caused by quality of the surface of drawn glass plates, because during production at temperatures in the glass production equipment, the drawn glass plates are placed or transported on guide plates made of zinc. At high temperatures of plates, zinc penetrates into the surface of the processed plates. Even the slightest content of zinc in the surface layer causes aggravation of the reflection capacity. The same effect also appears during the production of glass plates in every other method of production, in which guide plates have to be used, that with the current state of technology are exclusively made to contain zinc. Finally, documentation CZ 8371 describes a

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Brewster polariser that consists of a system of at least two adjoining glass reflection plates, where at least one black spacing insert is adjoining to one of its sides. The system of glass plates is inserted into the hole in the casing and locked together with the black spacing insert. Use of one black spacing insert cannot always comply with various manufacturing tolerances of glass reflection plates and their thermal expansion during operation of the instrument. This also causes a play between the glass reflection plates, which requires other black spacing inserts of different thickness to be used. The aim of the invention is to eliminate the disadvantage of the current state of the art and to provide an instrument for light therapy that has a higher light performance at the output, lower power consumption, generates less heat, is more hygienic and does not clog with contamination, does not clog optical equipment located at the output with contamination, enables improvement of existing healing effects and expansion of functions with massage effects, features a simple construction, can be handled more easily and features the same or lower demands and costs during production and assembly.

Disadvantages of the state of the art considerably eliminates and the aim of the invention meets an instrument for light therapy consisting of an outer casing with a front section terminated with the first hole, in which inner casing with a light source, reflector and Brewster polariser consisting of a system parallel glass plates lying on each other are located, while the output section of the inner casing reaching as far as the first hole of the outer casing holds a light filter, and with a rear section that changes into the second hole, in which fan for generation of pressure difference between both holes is located according to the

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invention consisting in that the system of glass plates of Brewster polariser is created by drawn glass plates with surface irregularities defining cavities of unequal shape between plates.

According to advantageous executions of the invention the outer side of the system of glass plates can be provided with insert with black surface that has profile patterns on the side of glass plates, massage ring can be allocated to the Brewster polariser, that is located in output section of inner casing and/or at the end of front part of outer casing. With advantage the massage ring can be provided with flexible massage elements, advantageously can be the massage ring provided with for generating a magnetic field outside the output hole of inner casing. Magnets can have with advantage a permanent or an electrical excitation. With advantage the massage ring can be a movable part of vibrator located at output section of inner casing and/or at the end of front section of outer casing. According to an advantageous execution there is fan allocated to Brewster polariser whereas this fan is set for airflow direction from the second hole of outer casing toward its first hole. With advantage there is lens allocated to Brewster polariser, which is located in output section of inner casing to focus rays reflected from the system of glass plates into the focus located outside outer casing on the optical axis of lens.

The construction is advantageous for improvement of the degree of utilisation of the reflected bundle of rays. In this construction, the elliptic reflector section is located against the parabolic reflector section so that optical axes of both reflector sections merge into a single optical axis. The light source is located in the primary focus of the elliptic reflector section, whose secondary focus is basically

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identical with that of the parabolic reflector section and the size of the elliptic reflector section is considerably smaller than that of the parabolic reflector. This system of reflectors, in fact, avoids diffuse light. With respect to simplification of production and reduction of requirements on accuracy of production of glass reflection plates, it is advantageous to use a construction, in which the Brewster polariser consists of three glass reflection plates that as a result of various surface irregularities create unequal gaps between each other and are terminated at least with one black spacing insert and are jointly inserted into the hole in the casing and locked by means of the carrier together with the black spacing insert. To enable simple amplification or attenuation of irradiation intensity or to regulate the size of the illuminated area, it is an advantage that the lens consists of a spherical convergent lens, whose focus lies on the optical axis in front of the cabinet in the direction of the outgoing light. The construction is also advantageous for improvement and intensification of programmable healing, irradiation and massage effects. According to this construction, a massage head is detachably fitted to the holder end. At its front part, this head is provided with flexible massage elements and is manually and/or electrically controlled. Circling motion of the massage head with flexible elements over the skin surface improves blood circulation in the skin and together with exhaustion of warm air it considerably improves the healing irradiation effects and adds also massage effects. Electrical control of the massage head, e.g. with vibrations, is another improvement of the instrument's function that enhances its utilisation in medicine and cosmetics. The vibration intensity and cycle length of the selected program can be remote controlled and changed by means

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of program buttons and buttons for amplification and attenuation of effects. Holder supports, air deflector for guiding air supplied by fan to cool the light source and Brewster polarised located within the cabinet are advantageous for amplification of the cooling effect. In order to keep cleanliness of the sucked air on the airtight construction of the optical equipment for guiding, polarisation and filtration of light, it is an advantage that air access holes are covered with a replaceable air filter, which helps to prevent contamination of the treated body surface areas. Further, it is advantageous to use the construction, in which the light filter has a colour shade that enables filtration of undesired light spectrum components. For use at rehabilitation centres when healing post-fracture, operation and burn states, the handling of the instrument is simplified so that the electrical outfit for the radiated light is fitted with a controller of program of healing, irradiation and massage functions controlled by means of program buttons and buttons for amplification and attenuation of effects with light and/or acoustic indication. This enables treatments to be performed at outpatient clinics and at beds without any undesired side effects. This is achieved by means of construction of the cabinet, enhanced construction of the Brewster polariser including simplification of glass reflection plates of the massage head and by means of introduction of remote control featuring a simple operation. The black spacing insert has a profiled surface that performs a function of a spring and flexibly compensates effects of manufacturing tolerances of thickness and thermal expansion of the system of glass reflection plates so that their tight seating onto each other in the hole of the inner casing after assembly is permanently guaranteed. Simple designation of the product and manufacturer

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is facilitated by the fact that the surface of the black spacing insert holds a marking, e.g. a trademark that is visible when looking into the instrument for light therapy against the direction of the outgoing polarised light. Thanks to the higher efficiency, the instrument for light therapy according to the invention has a considerably higher light performance at the output and thus lower power consumption and generates less heat at the outer side of glass plates of the Brewster polariser, it is more hygienic and does not clog with contamination, does not contaminate optical equipment located at the output with dust, thanks to devices allocated to the Brewster polariser it enables improvement of existing healing effects and expansion of functions with mechanical, magnetic and optical massage effects, it features a simple construction, is easy to handle and features the same or lower demands and costs during production and assembly.

The invention is explained in details by means of drawings. Figure 1 shows a longitudinal sectional view of the instrument for light therapy according to the invention. Figure 2 shows a detail of a longitudinal sectional view of glass plates of the Brewster polariser. Figure 3 shows a view of output section of the inner casing. Figure 4 shows a longitudinal sectional view of the massage ring with flexible massage elements. Figure 5 shows a longitudinal sectional view of the massage ring with permanent magnets and electromagnets. Figure 6 shows a longitudinal sectional view of massage ring consisting of a vibrator. Figure 7 shows an example of light path of bundle of rays.

According to Fig. 1, the instrument for light therapy consists of an outer casing 1 made of plastic. It is an advantage, that this casing is divided into two sections longitudinally connected either with screws or by means of

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latches and clamps. In the longitudinal sectional view, the outer casing 1 is shown as a double contour line. Basically, the outer casing 1 has a shape of a cranked cylinder with front section 120 and rear section 110. Fins not shown in the figure hold the inner casing 2 in the front section 120. This casing also has the shape of cranked cylinder. The outer side of the cranked section holds Brewster polariser 5 consisting of a system of drawn glass plates 511 attached to bearing plate 510 fitted into inner casing 2. Inner casing 2 is provided with hole 211 at one of its end. Shoulder of the hole holds reflector 222 that focuses rays generated by light source 233 fitted within reflector 222 by means of socket 224 and partly covered by known method with the other reflector 221. The other end of inner casing 2 changes into output section 230 with output hole 231. The recess (not show in the figure) of output section 230 of inner casing 2 holds filter 61 and lens 6 is located outside filter 61. Filter 61 and lens 6 are fixed in output section 230 of inner casing 2 by means of annular ring 233 of a suitable shape. Annular ring 233 holds massage ring 240 fitted with massage elements 241. It is an advantage that massage elements 241 can be made of a flexible material so that contact with the treated area does not cause irritation, but a desirable massage. Front section 120 of outer casing 1 changes into the rear section 110 either gradually or in the form of a crank. This rear section 110 holds fan 3 fitted in the outer casing, for example, by means of internal ribs 130. Rear section 110 of outer casing 1 is terminated with hole 111 in front of which air filter 112 is fitted. Supply cable 41 leading to switchboard 40 is taken from controller 42 to rear section 110 of outer casing 1. Cables are distributed from here to socket 224 of light source 223 and to fan 3. With its rear section 110, the instrument

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for light therapy can be seated in holder 10. Fan intakes air through hole 111, the air then passes through air filter 112, along blades of fan 3 and then it goes toward reflector 222 of light source 223. Socket 224 of light source 223 holds air deflector 225 that directs the airflow in the area of reflector 222 and brings the air into annular gap 131 between inner casing 2 and front section 120 of outer casing 1. Air passes through this gap 131 along Brewster polariser 5 and along output section 230 of inner casing 2 into the first hole 121 of front section 120 of outer casing 1 and out of the instrument through the first hole 121 in the direction to the treated area along massage ring 240. Light rays generated by light source 223 impinge on mirror surface of reflector 223 from which the rays are directed in a bundle to the surface of glass plates 511 of Brewster polariser 5, from which the rays are reflected under the known Brewster angle and being linear-polarised, they pass through filter 61. It is an advantage, that lens 6 is located behind filter 61 in the direction of rays. This lens focuses rays into the focus located on the optical axis of lens 6 outside of inner casing 2. According to Figure 2, drawn glass plates 511 are connected into a system, in which they are close to each other. Glass plates 511 manufactured by means of the draw technology have irregularities on their surfaces. Thickness of these irregularities can vary, but according to experience, it is advantageous the thickness to be about 1 mm. Due to air humidity, the plates are not self-sticky. There is zero mutual distance at contact points of adjacent glass plates 511 and the distance can vary in the cavity areas. Glass plates 511 have cavities 512 of various sizes between them, for example only microscopic ones that enable a different refraction of light. When the bundle of rays impinges on the first drawn

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glass plate 511, considerable part of rays is reflected under the Brewster angle. Part of the rays pass through the drawn glass plate 511 and cavities 512 of various sizes and impinge on the second of glass plates 511 under a changed angle as a result of light refraction index and depending on the thickness of glass plate 511 and cavity 512. Part of these rays is reflected back under the angle of incidence and part of the rays pass again through the drawn glass plate 511. This physical phenomenon repeats on every next glass plate 511 and terminates on black insert 520 with profiles on surface 521 that is bound on the last drawn glass plate 511. Drawn glass plates 511 can also have a different thickness. The optimum polarisation effect is achieved by means of a suitable combination of drawn glass plates 511. This increases efficiency of the Brewster polariser while considerably decreasing production costs on manufacture of drawn glass plates 511. Black insert 520 is seated on bearing plate 510 inserted into the recess in the hole of inner casing 2. Thanks to profiles of surface 521, black insert 521 is flexible and thus suitably compensates production tolerances and thermal expansion of the system of assembled drawn glass plates 511 so that they are permanently in close contact with each other. The profiled surface 521 of black plate 520 also enables the product to be marked in a simple way. A suitable shape of the recess formed in the profiled surface 521 can be used to mark instructions for use or manufacturer's trademark etc., because the profiled surface 521 is visible during operation of the instrument when viewed in the direction against the outgoing polarised light. Figure 3 shows the front section 120 of outer casing 1, from which collar 233 of output section 230 not shown in the figure is protruding from the first section 121. According to Figure 4, the simple implementation of massage

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ring 240 is provided with flexible massage elements 241. According to Figure 5, permanent magnets 242 or electromagnets 243 connected with electrical socket 247 for connection to a power supply source are located in the body of massage ring 240. According to Figure 6, it is an advantage, that massage ring 240 is a movable component of vibrator 248. Vibrator 248 consists of collar 234 as a fixed component embedded in output section 230 of inner casing 2 and/or hole 121 of outer casing 1, further as an example, it consists of flexible attachment 246, massage ring 240 that forms the movable component and tools for generating oscillating motions of massage ring 240 that, as an example, consist of electromagnets 243 connected with electric terminal 247 for connection to electrical power supply. The shown flexible attachment 246 is only as an example and can also be replaced with push-type attachment of massage ring 240 in collar 234 for oscillating motions either in axial direction or for rotary-oscillating motions along the axis of massage ring 240. When implementing massage ring 240, together with light effects it is also possible to perform massage of surface of the treated area. Circling or oscillating motions of the instrument, when the instrument is manual-controlled utilise the advantage of flexible massage elements 241. It is an advantage, that the manual control can be substituted with a vibrator as mentioned above. It is an advantage, that programmable functions of controller 42 can be utilised, which enable programmable amplification and attenuation of vibrations, light flow, flow speed and temperature of the airflow. Exhausting of warm air onto the treated area is also important for the healing effect, namely because warm air according of the invention is exhausted outside the circle formed by massage ring 240. According to the advantageous implementation of the instrument for light

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therapy according to Figure 7, reflector 222 has a parabolic reflection plane 252. Another elliptic reflector 221 with elliptic reflection plane 251 is situated against the parabolic reflector 222 so that optical axes 501 and 502 are identical. Light source 223 is located in primary focus F1 of part of elliptic reflector 221 and whose secondary focus is identical with focus F2 of parabolic reflector 222, i.e. with the focus of parts of parabolic reflector 222, if the reflector is divided into several parts. Reflection plane 251 of elliptic reflector 221 is considerably smaller than reflection plane 252 of parabolic reflector 222. Such configuration considerably restricts diffusion of light radiated by light source 223. It is an advantage, that after passing through filter 61, the bundle of rays reflected from the Brewster polariser is focused by lens 6 into focus F3 located on optical axis 503 outside the outer casing that is not shown. The instrument for light therapy can be used not only for stimulation of biological processes when healing surface wounds on bodies, but also in other branches of medicine, cosmetics and biology. It can be used in physical treatment in the branch of mouth, jaw and face surgery.

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Patent claims

1. The instrument for light therapy, consisting of an outer casing with a front section terminated with the first hole, in which inner casing with a light source, reflector and Brewster polariser consisting of a system parallel glass plates lying on each other are located, while the output section of the inner casing reaching as far as the first hole of the outer casing holds a light filter, and with a rear section that changes into the second hole, in which fan for generation of pressure difference between both holes is located,

c o n s i s t i n g i n t h a t
the system of glass plates of Brewster polariser (5) consists of drawn glass plates (511) with surface irregularities defining cavities (512) of unequal shape between plates (511).

2. Instrument for light therapy according to claim 1,
c o n s i s t i n g i n t h a t
the outer side of the system of glass plates (511) is provided with insert (520) with black surface that has profile patterns on the side of glass plates (511).

3. Instrument for light therapy according to claim 1,
c o n s i s t i n g i n t h a t
massage ring (240) is allocated to the Brewster polariser, that is located in output section (230) of inner casing (2) and/or at the end of front part (120) of outer casing (1).

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4. Instrument for light therapy according to claim 3, consisting in that massage ring (240) is provided with flexible massage elements (241).

5. Instrument for light therapy according to claim 3, consisting in that massage ring (240) is provided with magnets (242, 243) for generating a magnetic field outside the output hole (231) of inner casing (2).

6. Instrument for light therapy according to claim 5, consisting in that magnets (242, 243) are permanent or with electrical excitation.

7. Instrument for light therapy according to claim 4, consisting in that massage ring (240) is a movable part of vibrator (248) located at output section (230) of inner casing (2) and/or at the end of front section (120) of outer casing (1).

8. Instrument for light therapy according to claim 1 - 7, consisting in that there is fan (3) allocated to Brewster polariser (5). This fan is set for airflow direction from the second hole (111) of outer casing (1) toward its first hole (121).

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9. Instrument for light therapy according to claim 1,
c o n s i s t i n g i n t h a t
there is lens (6) allocated to Brewster polariser (5), which
is located in output section (230) of inner casing (2) to
focus rays reflected from the system of glass plates (511) into
the focus located outside outer casing (2) on the optical axis
of lens (6).

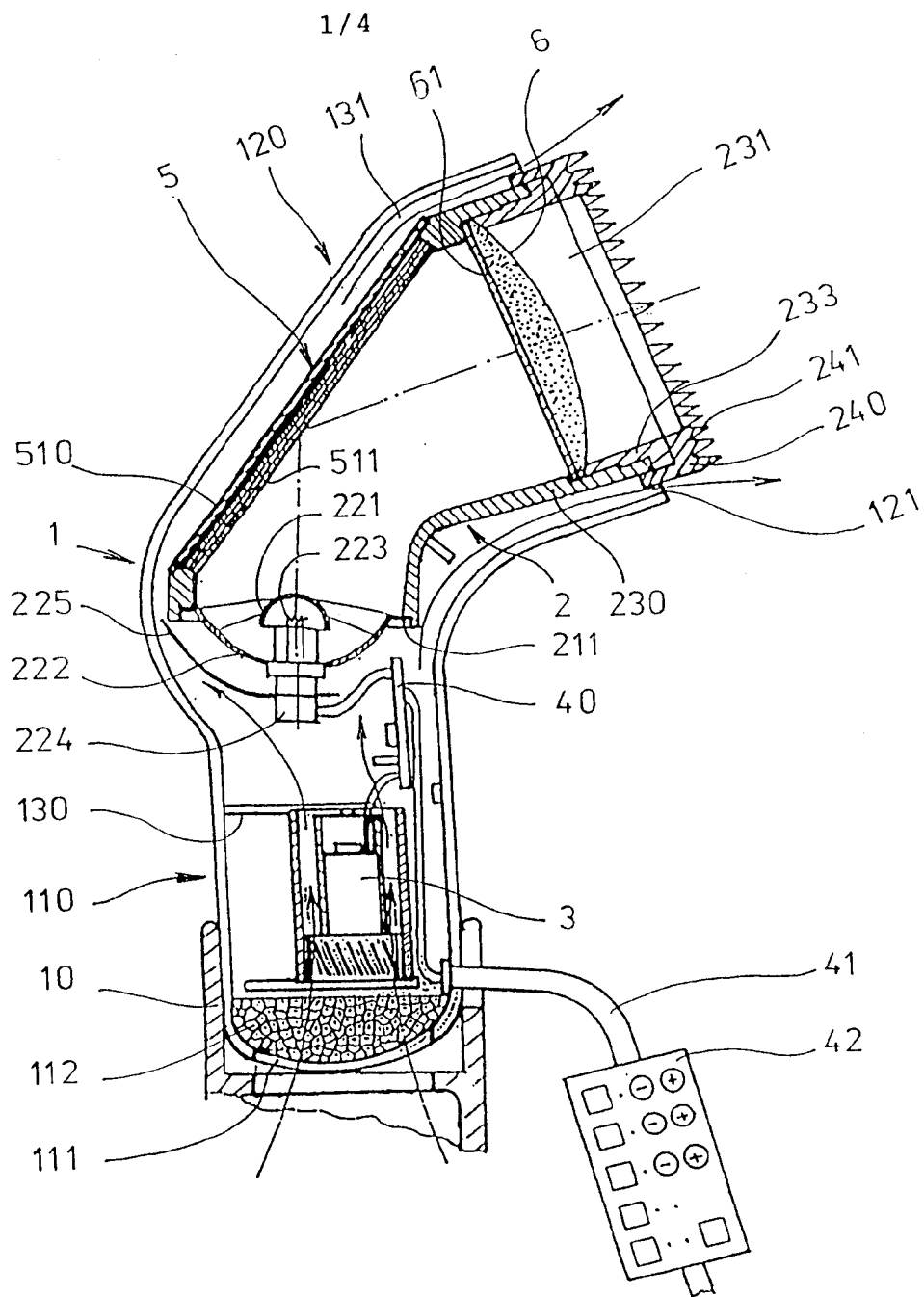


Fig. 1

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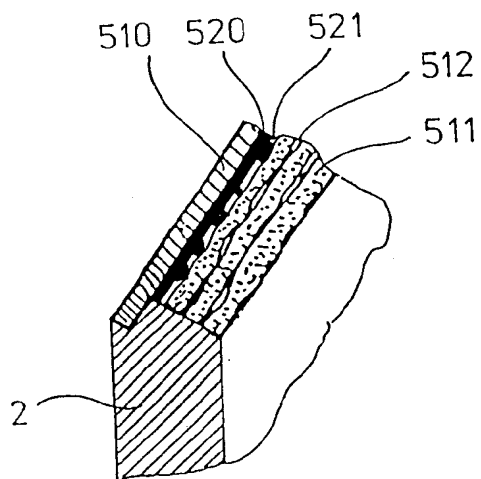


Fig. 2

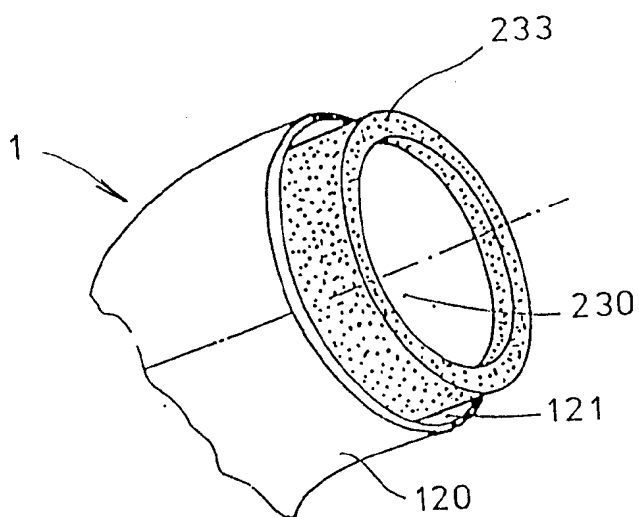


Fig. 3

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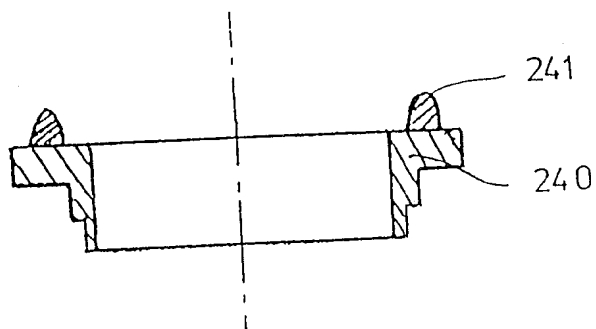


Fig. 4

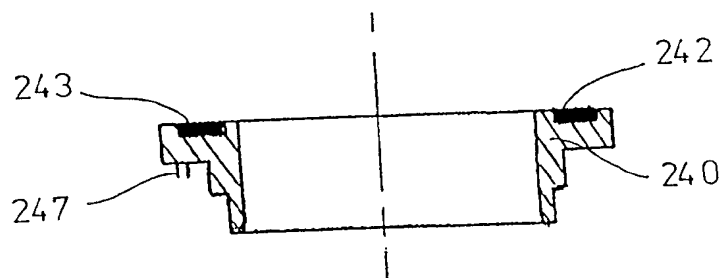


Fig. 5

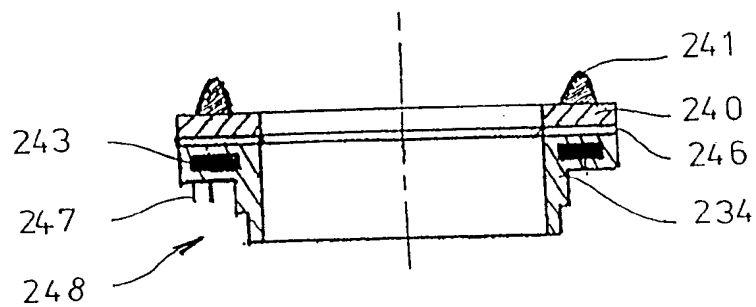


Fig. 6

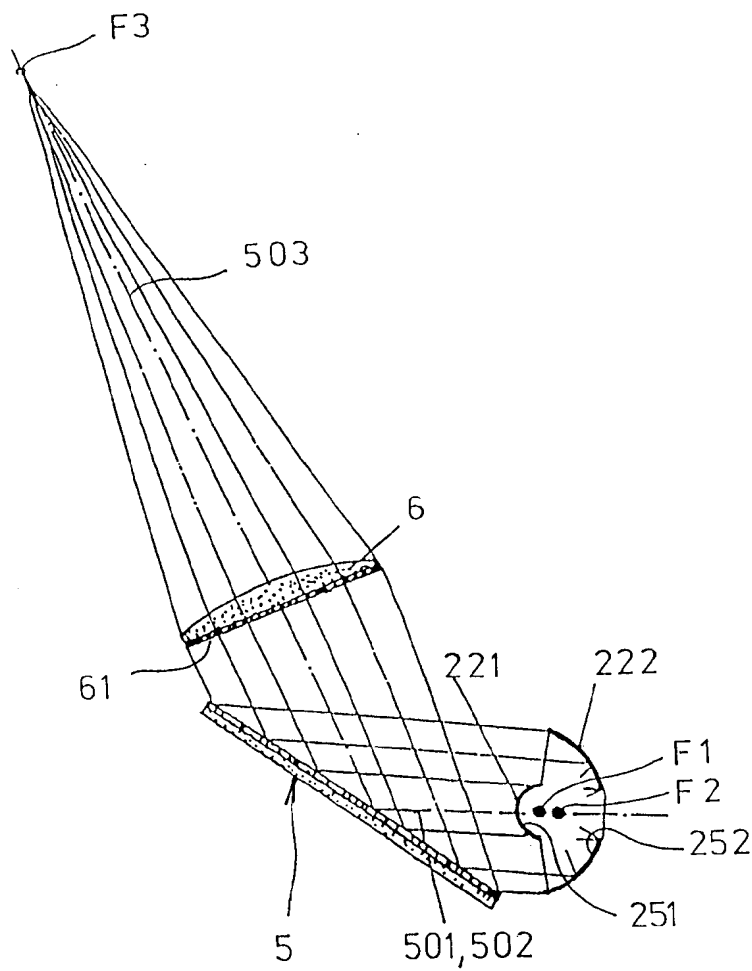


Fig. 7

INTERNATIONAL SEARCH REPORT

International Application No

PCT/CZ 99/00044

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 A61N5/073 A61H23/02 F21V9/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 A61N A61H F21V

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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INTERNATIONAL SEARCH REPORT

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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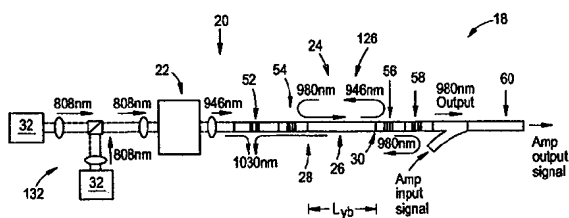
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(54) Title: SEMICONDUCTOR-SOLID STATE LASER OPTICAL WAVEGUIDE PUMP DEVICE AND METHOD



(57) Abstract

The invention includes a solid state laser (22) which outputs wavelength emission λ_{ss} centered about 946 nm, combined with a lasering waveguide (24) which includes a Yb doped optical waveguide (26) such that when the λ_{ss} output is inputted into the lasering waveguide (24) the lasering waveguide produces a wavelength emission λ_y centered about 980 nm. The invention further includes the utilization of pump light with optical waveguide amplifying device.

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**SEMICONDUCTOR-SOLID STATE LASER OPTICAL WAVEGUIDE PUMP
DEVICE AND METHOD**

CROSS-REFERENCE TO RELATED APPLICATIONS

5 This application claims priority to U.S. Provisional patent Application Serial No. 60/115,229, filed on January 8, 1999, the content of which is relied upon and incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

10 The present invention relates generally to optical waveguide devices, semiconductor lasers, solid state lasers, and particularly to the utilization of lasers to pump optical waveguide amplifiers.

 Optical amplifiers and lasers are important components used in optical fiber telecommunications systems. Optical signals transmitted in optical fibers tend to
15 weaken as they travel along the optical fibers. Optical amplifiers provide an economic means of amplifying such weakened optical signals while maintaining the optical nature of the signal.

 Erbium doped optical fiber amplifiers have become the dominant means of amplifying optical signals in the 1550 nm optical telecommunications window. Such
20 erbium doped optical fiber amplifiers are normally directly pumped with 980 nm and/or 1480 nm semiconductor pump lasers. With such an amplifier-pump system, electrical energy applied to the 980 nm (1480 nm) semiconductor pump laser produces 980 nm (1480 nm) photons which are coupled through an optical fiber pigtail into the erbium doped optical fiber. The 980 nm and/or 1480 nm pump light excites/energizes the

erbium ions in the erbium doped optical fiber so that 1550 nm optical telecommunications signals are amplified by the excited/energized erbium ions. Such direct optical pumping of optical amplifiers with semiconductor produced photons has become the standard in the optical telecommunications industry because of reliability and related use requirements, for example compact space utilization. But, in addition to economic expense problems, such direct semiconductor pump lasers pose problems in terms of already reaching maximum optical output power limitations while the development of optical amplifiers has continued to require higher and higher pump power input requirements. It appears that the commercially available maximum reliable output power of 980 nm semiconductor laser pumps may plateau in the 300 mW output power range while the input pump power requirements of optical amplifiers continue to climb. Semiconductor laser research and development continue to strive towards improving the structure and performance of 980 nm semiconductor laser pumps in an effort to try to meet the needs of optical amplifiers.

The optical amplifier industry needs a pump laser technology that is able to meet its ever increasing optical power demands.

SUMMARY OF THE INVENTION

One aspect of the present invention is an optical waveguide device which includes a solid state laser which outputs wavelength emission λ_{ss} centered about 946 nm, combined with a lasing waveguide which includes a Yb doped optical waveguide such that when the λ_{ss} output is inputted into the lasing waveguide the lasing waveguide produces a wavelength emission λ_y centered about 980 nm.

In another aspect, the present invention includes a method of producing 980 nm optical amplifier pump wavelength light which includes providing a first laser for producing an emission λ_1 , inputting the produced emission λ_1 into a second laser for producing an emission λ_2 , producing an emission λ_2 , inputting the produced emission λ_2 into a third laser for producing an emission λ_3 centered about the 980 nm optical amplifier pump wavelength.

In a further aspect the invention includes an optical amplifier device which includes at least one semiconductor laser which produces an emission λ_1 , centered about 808 nm, a first solid state laser which is optically pumped by the semiconductor

laser such that it produces an emission λ_2 centered about 946 nm, a second solid state laser which is optically pumped by the first solid state laser such that it produces an emission λ_3 centered about 980 nm, and an optical amplifier waveguide for amplifying an optical transmission signal wherein the optical amplifier is optically pumped by the second solid state laser.

The invention further includes a method of amplifying an optical transmission signal which comprises the steps of: providing a first laser for producing λ_1 light, a second laser for producing λ_2 light, and a third laser for producing λ_3 light, and an optical amplifier which utilizes λ_3 light to amplify an optical signal; pumping the second laser with λ_1 light produced by the first laser; pumping the third laser with λ_2 light produced by the second laser; and pumping the optical amplifier with λ_3 light produced by the third laser.

Additionally, the invention includes a method of making a 980 nm pump for an optical amplifier, with the method including: providing at least one semiconductor laser diode, coupling the semiconductor laser diode into a Nd:YAG laser, and coupling the Nd:YAG laser into a Yb doped optical waveguide fiber laser.

In a further aspect the invention includes an optical amplifier system comprising a single cladding optical waveguide lasing fiber and a multimode pump source.

The invention further comprises a method of making an optical amplifier pump, which includes providing a multimode pump source; providing a single cladding optical waveguide lasing fiber; and indirectly pumping the lasing fiber with the multimode pump source.

Additionally the invention includes the method of amplifying an optical signal λ_i , by providing a multimode light pump source having a wavelength λ_{mm} multimode brightness output; converting the multimode brightness output into a single mode output having a wavelength λ_{pump} ; and inputting the single mode output into an optical amplifier for amplifying an optical signal λ_i .

In a further aspect the invention includes an optical amplifier pump for pumping an optical amplifier with a pump wavelength λ_{pump} , where the pump includes a semiconductor laser which produces a wavelength λ_{semi} and the pump outputs at least 500 mW of light at λ_{pump} .

Additionally the invention includes an optical amplifier pump comprising:
a semiconductor laser which produces a wavelength λ_1 for pumping Nd ions; a plurality
5 of Nd ions, which when pumped by the wavelength λ_1 , produces a wavelength λ_2 for
pumping Yb ions; and a plurality of Yb ions, which when pumped by the wavelength λ_2
produces a wavelength λ_3 for pumping Er ions.

In a further aspect the invention includes an optical amplifier pump for pumping
an optical amplifier which amplifies optical signals in the range of 1560 to 1620 nm (L-
10 band), which has at least one broad area semiconductor laser; and a neodymium doped
solid state laser, with solid state laser pumped by the semiconductor laser.

Additionally the invention includes an optical amplifier that comprises
a semiconductor laser; a solid state laser, the solid state laser pumped by the
semiconductor laser; and an Er doped optical amplifier fiber, with the Er doped optical
15 amplifier fiber for amplifying signals in the range of 1560 to 1620 nm and pumped by
the solid state laser.

In a further aspect the invention includes a method of amplifying a L-band
optical signal by providing an Er doped optical fiber, pumping a neodymium solid
state laser with a broad area semiconductor laser, inputting said solid state laser directly
20 into the Er doped optical fiber, and amplifying a L-band optical signal with the Er
doped optical fiber.

Additional features and advantages of the invention will be set forth in the
detailed description which follows, and in part will be readily apparent to those skilled
in the art from that description or recognized by practicing the invention as described
25 herein, including the detailed description which follows, the claims, as well as the
appended drawings.

It is to be understood that both the foregoing general description and the
following detailed description are merely exemplary of the invention, and are intended
to provide an overview or framework for understanding the nature and character of the
30 invention as it is claimed. The accompanying drawings are included to provide a
further understanding of the invention, and are incorporated in and constitute a part of
this specification. The drawings illustrate various embodiments of the invention, and

together with the description serve to explain the principles and operation of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic representation in accordance with the present invention.

FIG. 2 is schematic representation in accordance with the present invention.

FIG. 3 is schematic representation in accordance with the present invention.

FIG. 4 is a graph of output power (milliwatts) at 980nm versus input power (milliwatts) at 946nm.

FIG. 5 is an output spectrum plot of light from a Yb fiber laser.

FIG. 6 is an output spectrum plot of light, which shows three output spectrums from Yb fiber lasers.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Reference will now be made in detail to the present preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings. An exemplary embodiment of the present invention is shown in Figure 1. The laser system of the invention is designated generally throughout by reference numeral 20.

In accordance with the invention, the present invention for an optical waveguide device 18 includes a solid state laser 22. Solid state laser 22 outputs a wavelength emission λ_{ss} centered about 946 nm. Solid state laser 22 provides a reliable source for producing a high powered laser light output centered about 946 nm. Preferably solid state laser 22 is a neodymium doped solid state laser.

Solid state laser 22 is preferably a neodymium doped solid state laser, such as the Nd:YAG solid state laser shown in FIGS. 2, that is pumped by two semiconductor laser diodes 32. Preferred semiconductor lasers for pumping the neodymium doped solid state laser are semiconductor lasers that emit light having a wavelength X with X selected from the Nd absorption bands near 880nm (from about 860 to about 900nm), 808nm (from about 780 to about 830nm), 740nm (from about 720 to about 760nm), and 690nm (from about 670 to about 710nm). These Nd absorption wavelength bands are for the Nd solid state YAG host, and with other solid state hosts for Nd the

wavelengths and widths of these Nd absorption bands may vary. Preferably laser diodes 32 are broad area lasers with each producing about 2 watts of multimode light (2W MM) at 808 nm. With optical element lenses 34 and a polarization combiner 36, the output of broad area laser diodes 32 is inputted into Nd:YAG solid state laser 22.

5 Nd:YAG solid state laser 22 is comprised of a 946 nm laser cavity 38 which includes Nd:YAG crystal 40 and glass substrate spherical surface laser element 42. Nd:YAG crystal 40 includes a 946 nm high reflectivity (about 99%) coating 44 and an anti-reflection coating 48 that prevents reflections (946 nm and 1060 nm) other than at 808 nm, coating 48 may include a 808nm high reflector to provide beneficial reflection of

10 808nm light. Spherical surface laser element 42 includes a coating 50 that provides for high reflectivity (about 95%) at 946 nm and high transmission at 1060 nm. Solid state laser 22 preferably produces at least about 1 watt of single mode light at 946 nm. Preferably light in the range of 780 to 880 nm is inputted into solid state laser 22, most preferably 800 to 880 nm. In addition to this external cavity solid state Nd doped

15 crystal embodiment of solid state laser 22, solid state laser 22 may comprise a tapered Nd doped waveguide laser device or a Nd doped double clad optical waveguide fiber laser device.

As shown in FIG. 1, optical waveguide device 18 includes a lasing waveguide 24 that is comprised of a Yb doped optical waveguide 26. Yb doped optical waveguide

20 26 has an input end 28 and an output end 30. Input end 28 is optically coupled to solid state laser 22 such that the emission λ_{ss} outputted from solid state laser 22 is inputted into the lasing Yb doped optical waveguide and an emission λ_y centered about 980 nm is outputted from lasing waveguide output end 30.

Yb doped optical waveguide 26 is preferably a silica optical waveguide fiber that is doped with Yb. It is further preferred that the silica optical fiber is an aluminosilicate fiber such as a silica optical fiber doped with Al and Yb. In a most preferred embodiment the Yb doped optical waveguide is Er free, in that the waveguide does not contain erbium so that the Yb ions are the excitable ions in the waveguide. Preferably the Er free Yb doped waveguide is a silica waveguide fiber.

30 Preferably the Yb doped silica fiber is comprised of 60 to 99 wt.% SiO_2 . Preferably Yb doped waveguide 26 is a silica fiber which includes 0.1 to 4 wt.% Yb and 0.1 to 10 wt.% Al, and most preferably a waveguide with 0.2 to 2.5 wt.% Yb and

0.2 to 9wt.% Al, with a further preferred Al wt.% of 0.2 to 8.3wt.% Al.. In a preferred embodiment the Yb doped silica fiber composition further comprises Ge (germanium).

It is preferred that lasing waveguide 24 and Yb doped optical waveguide 26 are comprised of single mode optical waveguide fiber with such single mode optical
5 waveguide fiber the guiding of light by the waveguide is restrained to a single mode. Additionally, Yb doped optical waveguide 26 is preferably a single cladding optical fiber, in that the optical fiber has a single clad as compared to a double clad optical fiber or other multi-clad fibers. Preferably Yb doped waveguide 26 consists essentially of a single waveguide cladding and a waveguiding core so that the optical waveguide
10 fiber only has a single waveguide cladding surrounding a waveguide core with appropriate optical fiber protective coatings.

As shown in FIG. 1, optical waveguide device 18 includes a filter 52. Filter 52 is a filter for inhibiting light having a wavelength λ_x centered about 1030 nm from propagating in Yb doped optical waveguide 26. Light removal filter 52 removes 1030
15 nm light so that light produced in the Yb doped waveguide 26 is biased towards the production of 980 nm light. Preferably filter 52 is positioned outside of the 980 nm resonant cavity and most preferably is a fiber grating positioned between solid state laser 22 and Yb doped optical waveguide input end 28. As depicted in FIG. 1, fiber filter 52 is preferably a long period fiber grating that removes unwanted 1030 nm light
20 that may be produced by solid state laser 22. Filter 52 removes and prevents detrimental light having a wavelength centered about 1030 nm from degrading the performance of lasing waveguide 24 and ensures that the beneficial 946 nm excitation light is utilized by Yb ions to produce 980 nm light and to suppress the production of 1030 nm light by Yb ions in Yb doped waveguide 26. In addition to a long period
25 grating, filter 52 can comprise a filter such as a dielectric thin film filter which also removes the unwanted 1030 nm light that is produced by excited Yb ions.

As shown in FIG. 1, lasing waveguide 24 preferably includes at least one fiber Bragg grating. Fiber Bragg gratings provide a beneficial means of reflecting light in an optical fiber waveguide format. Lasing waveguide 24 includes a back reflector 54
30 proximate Yb doped optical waveguide input end 28. Back reflector 54 is centered about 980 nm and is highly reflective so as to benefit the output of 980 nm light from the lasing waveguide. Lasing waveguide 24 includes a pump reflector 56 proximate Yb

doped optical waveguide output end 30. Pump reflector 56 is centered about 946 nm and is highly reflective so that 946 nm pump light that reaches the end of the Yb doped waveguide is contained in the Yb doped waveguide so that it can pump Yb ions into the proper excited state. Lasing waveguide 24 includes an output coupler 58 proximate Yb doped optical waveguide output end 30. Output coupler 58 is centered about 980 nm and is less reflective than back reflector 54 so as to benefit the output of 980 nm light from the lasing waveguide. Output coupler 58 and back reflector 54 are fiber Bragg gratings that provide reflectivity of light to benefit the lasing operation. Pump reflector 56 is also a fiber Bragg grating that provides beneficial reflections. These fiber Bragg gratings can be made in separate optical waveguide fibers which are spliced together with Yb doped optical waveguide fiber 26 to form lasing waveguide 24 or could be one unitary, integral, and complete single optical fiber or spliced variations thereof.

Yb doped optical waveguide 26 has a gain G_{980} at 980 nm and a gain G_{1030} at 1030 nm with $G_{980} > G_{1030}$. Output coupler 58 of lasing waveguide 24 has a reflectivity OCR, and Yb doped waveguide 26 has a Yb weight percent concentration $CONC_{Yb}$, a pump absorption PA_{946} at 946nm (percent of 946nm pump power absorbed by the Yb ions) which depends on the 946 nm pump power and the removal of 1030 nm light by 1030 nm light removal filter 52, and a length L_{Yb} , wherein gain G_{980} is dependent on $CONC_{Yb}$, PA_{946} and OCR and the waveguide length L_{Yb} is optimized such that $G_{980} > G_{1030}$ with G_{980} depending on $CONC_{Yb}$, OCR, PA_{946} and L_{Yb} . For a given $CONC_{Yb}$, PA_{946} and OCR, the length L_{Yb} is set at an optical length so that $G_{980} > G_{1030}$ and beneficial production of 980 nm light is obtained. In practicing the invention it has been found that for a $CONC_{Yb}$ of about 0.2 wt.% Yb, a PA_{946} greater than 90% (with the long period fiber grating filter removing 1030 nm light), and an OCR reflectivity of about 5% at 980 nm, that the optimized optical fiber length is at about 60 cm. For a given inputted pump power the length is adjusted to insure $G_{980} > G_{1030}$. If light removal long period fiber grating filter 52 is not utilized to remove 1030 nm light and bias the production of 980 nm light by 946 nm pump light, then PA_{946} needs to be kept below 60% so that $G_{980} > G_{1030}$ and to maintain the production of 980 nm which results in wasting 946 nm pump power.

Optical waveguide device 18 of the invention provides at least 300 milliwatts (mW) of 980 nm output which is readily usable for pumping an optical amplifier and

meets the high pump power demands of optical amplifiers. Preferably lasing waveguide 24 produces a 980 nm single mode output of at least .5W (a half of a watt). Yd doped optical waveguide output end 30 is optically coupled to an Er doped optical amplifier 60 as depicted in FIG. 1. As such, the invention comprises an optical amplifier pump that produces at least 500 milliwatts of 980 nm pump power and includes a semiconductor laser. Preferably the waveguide device of the invention has a Yb laser slope efficiency of at least 80%. With such, the inventive device provides an optical to optical conversion efficiency greater than 25% (1 W out at 980nm, 4W in at 808nm), preferably greater than 30%, more preferably greater than 40%, and most preferably greater than 50%.

The invention further includes a method of producing a 980 nm pump light. This method of producing a 980 nm pump light includes the steps of providing a first laser for producing an emission λ_1 centered about 808 nm; inputting the emission λ_1 into a second laser for producing an emission λ_2 centered about 946 nm; producing emission λ_2 , centered about 946 nm; inputting the produced emission λ_2 into a third laser for producing an emission λ_3 centered about 980 nm; and then producing emission λ_3 centered about 980 nm.

The step of providing a first laser for producing λ_1 and inputting λ_1 includes providing a semiconductor laser 32 and coupling semiconductor laser 32 into solid state laser 22. The method preferably includes providing a second semiconductor laser 32 for producing the emission λ_1 centered about 808 nm, and polarization multiplexing or wavelength multiplexing the first laser 32 and the second semiconductor laser 32. Preferably first laser 32 and second semiconductor laser 32 are broad-area laser diodes which produce a multimode emission λ_1 .

Preferably the second laser which provides emission λ_2 centered about 946 nm is a solid state laser 22, most preferably a Nd doped laser, such as a Nd:YAG laser which comprises a Yd doped solid state lasing waveguide laser, such as a Yb doped laser fiber 26.

Preferably the method of producing a 980 nm pump light includes the step of inhibiting the feedback of 1030 nm light into third laser 24, such as by filtering with filter 52. As shown in FIG. 1, the method further includes inputting the produced emission λ_3 centered about 980 nm into Er doped optical amplifier 60.

In a further aspect the invention includes an optical amplifier device 18 which includes a semiconductor 32 which produces an emission λ_1 centered about a first semiconductor wavelength and a first solid state laser 22 which is optically pumped by semiconductor laser 32. First solid state laser 22 produces an emission λ_2 centered
5 about a first solid state wavelength in the Yb absorption spectrum peak that is centered about 920 nm. The device further includes a second solid state laser 24 that is optically pumped by first solid state laser 22. Second solid state laser 24 produces an emission λ_3 centered about 980 nm and optical amplifier 60 for amplifying an optical transmission signal is optically pumped by second solid state laser 24. Preferably the
10 first solid state laser 22 is a Nd doped laser and the first solid state wavelength is in the range of 880 to 960 nm. Preferably second solid state laser 24 is comprised of an optical waveguide which includes a Yb doped silica optical waveguide fiber 26. Additionally, second solid state laser 24 preferably includes a fiber Bragg grating back reflector 54 and a fiber Bragg grating pump reflector 56. In a most preferred
15 embodiment of the invention the device includes filter 52 for inhibiting light having a wavelength proximate 1030 nm from entering second solid state laser 24.

The invention further includes a method of amplifying an optical transmission signal, which includes: providing a third laser for producing λ_3 light; providing an optical amplifier which utilizes λ_3 light to amplify an optical signal; pumping the
20 second laser with λ_1 light produced by the first laser, pumping the third laser with λ_2 light produced by the second laser, and pumping the optical amplifier with the λ_3 light. Preferably with the method $\lambda_3 > \lambda_2 > \lambda_1$, and most preferably the method includes amplifying an optical transmission signal which has a wavelength λ_4 such that $\lambda_4 > \lambda_3 > \lambda_2 > \lambda_1$. In preferred methods: λ_1 light is centered about 808 nm; λ_2 light is centered
25 about 946 nm; and λ_3 light is centered about 980 nm. The method also further includes suppressing light having a wavelength centered about 1030 nm, such as with a filter 52.

The invention further comprises a method of making a 980 nm pump for an optical amplifier which includes the steps of providing at least one semiconductor laser diode, coupling at least one semiconductor laser diode into a solid state laser, and
30 coupling the solid state laser into a Yb doped optical fiber laser. Preferably the step of providing at least one semiconductor laser diode 32 comprises providing at least two semiconductor laser diodes 32, most preferably providing two broad area

semiconductor lasers with each of the semiconductor lasers outputting at least 2W (two watts) each at a wavelength centered about 808 nm and coupling into a solid state laser includes combining the polarization of the two semiconductor lasers. Preferably the solid state laser 22 comprises a Nd doped solid state laser. Preferably Yb doped optical waveguide fiber laser 24 comprises a single clad single mode alumino-silicate Yb doped fiber 26.

In an additional aspect, the invention includes an optical amplifier system that comprises a single cladding optical waveguide lasing fiber and a multimode pump source. As shown in FIG. 1, the optical amplifier system of the invention comprises single cladding optical waveguide lasing fiber 126 and multimode pump source 132. Preferably single cladding optical waveguide lasing fiber 126 comprises a single mode Yb doped optical 26 and multimode pump source 132 is comprised of a first and second broad area semiconductor laser 32. Most preferably the single cladding optical waveguide lasing fiber is indirectly pumped by said multimode pump source.

Additionally, the invention includes a method of making an optical amplifier pump which comprises providing a multimode pump source 132, providing a single cladding optical waveguide lasing fiber 126 and indirectly pumping the lasing fiber 126 with multimode pump source 132.

In a further aspect the invention comprises a method of amplifying an optical signal λ by providing a multimode light pump source having a wavelength λ_{mm} multimode brightness output; converting the multimode brightness output into a single mode output having a wavelength λ_{pump} ; and inputting the single mode output into an optical amplifier for amplifying an optical signal λ . Preferably $\lambda > \lambda_{pump} > \lambda_{mm}$.

Additionally, the invention includes an optical amplifier pump for pumping an optical amplifier with a pump wavelength λ_{pump} , with the pump including a semiconductor laser which produces a wavelength λ_{semi} and the pump outputting at least 500mW of light at λ_{pump} . Preferably λ_{semi} is not equal to λ_{pump} ($\lambda_{semi} \neq \lambda_{pump}$) and most preferably λ_{semi} is less than λ_{pump} ($\lambda_{semi} > \lambda_{pump}$). Preferably λ_{semi} is in the range of 780 to 880 nm, and most preferably λ_{semi} is at a wavelength which excites neodymium ions. In a preferred embodiment λ_{pump} is centered about 946 nm. In a further preferred embodiment λ_{pump} is centered about 980 nm.

In a further aspect the invention includes an optical amplifier pump with a semiconductor laser which produces a wavelength λ_1 for pumping Nd ions, a plurality of Nd ions which when pumped by the wavelength λ_1 produces a wavelength λ_2 for pumping Yb ions, and a plurality of Yb ions which when pumped by the wavelength λ_2 produces a wavelength λ_3 for pumping Er ions. Preferably λ_1 is in the range of 780 to 880 nm, λ_2 is in the range of 900-960 nm, and λ_3 is in the range of 970-980 nm.

In addition, the invention includes an optical amplifier pump for pumping an optical amplifier which amplifies optical signals in the L-band range of 1560 to 1620 nm which comprises at least one broad area semiconductor laser and a neodymium doped solid state laser with the neodymium doped solid state laser pumped by the semiconductor laser. As shown in FIG. 3, optical amplifier pump 120 comprises using the first part 110 of laser system 20 of FIG. 1 to directly pump L-band optical amplifier 160 with the 946 nm output from Nd doped solid state laser 22. Broad area semiconductor lasers 32 pump solid state laser 22 which inputs the 946 nm light directly into L-Band optical amplifier 160 without utilizing the Yb doped optical fiber. Pump 120 effectively pumps an L-band optical amplifier such as a long length of Er doped Al doped silica amplifier fiber.

The application of the invention to directly pump a L-band optical amplifier includes an optical amplifier 160 which has a semiconductor 32, a solid state laser 22 which is pumped by semiconductor laser 32, and an Er doped optical amplifier fiber 260 for amplifying signals in the range of 1560 to 1620 nm with the amplifier fiber pumped by solid state laser 22. Preferably Er doped optical amplifier fiber 260 is a long length of fiber having a length in the range of 50 to 250 meters, and more preferably 100 to 200 meters. Preferably solid state laser 22 is comprised of neodymium, such as a neodymium doped solid state laser. Preferably semiconductor lasers 32 are broad area multimode semiconductor lasers. The neodymium doped solid state laser may comprise a Nd doped crystal, a Nd doped double clad waveguide, or a Nd doped tapered waveguide. A Nd doped crystal is the preferred solid state laser, with Nd:YAG most preferred.

The invention includes a method of amplifying a L-band optical signal which includes the steps of providing an Er doped optical fiber, pumping a neodymium solid state laser with a broad area semiconductor laser, inputting the solid state laser directly

into the Er doped optical fiber, and amplifying a L-band optical signal with the Er doped optical fiber. In a preferred method the provided Er doped fiber has a length of at least 100 meters, and most preferably has a length from 100 to 200 meters. Most preferably the Er doped optical fiber is an Al doped silica fiber.

5

Examples

The invention will be further clarified by the following examples which are intended to be exemplary of the invention.

10 Example 1-2

As shown in FIG.1-2, a single-mode Yb:SiO₂ fiber laser pumped by a diode-pumped 1.1 W Nd:YAG laser at 946 nm in accordance with the invention provided >650 mW output power at 980 nm and >80% slope efficiency. Such high output power at 980 nm was achieved by pumping at 946 nm using a TEM_{0,0} laser-diode-pumped Nd:YAG. Although the Yb absorption cross section has a minimum near this wavelength, there was still enough absorption to provide the 980nm output. This inventive pumping scheme obtained 0.65 W of single-mode output from a CS980 brand optical fiber (Corning Incorporated; Corning, NY) output fiber, and is scaleable to much higher output powers and has been found to be useful for pumping Er-doped amplifiers. In this high output power operation of the invention the 1030 nm transition was suppressed.

In practicing the invention as shown in FIG. 1 and described herein, the invention involves the quasi-four-level transition of Nd:YAG at 946 nm to directly pump Yb:SiO₂ which lases at 980 nm and directly pumps Er. Such production of 980 nm pump light has provided certain advantages such as compatibility with existing amplifier component technology and pre-amp stage pumping without significant NF degradation as observed with Yb:Er co-doped fibers.

As shown in FIG 1-2, the TEM_{0,0} pump laser consisted of a Nd:YAG solid state crystal pumped by a pair of polarization-multiplexed 2W multimode, broadened-waveguide, broad-area semiconductor laser diodes at 808 nm with emitting aperture of 100 X 1 μm². The solid state laser crystal had a 1 dB absorption length of 3 mm, and dimensions 3X3X8 mm. The plano-concave resonator had a length of 7 mm (optical

30

length is 1 cm). The radius of curvature was about 10 cm and the thermal lens at 4 W pump power was about 15 cm. Thermal lensing caused the resonator spot size to decrease with increasing pump power, and therefore beam divergence increased with pump power. This was verified experimentally, with measured TEM_{0,0} beam
5 divergence in the range 3.4-6 mrad, depending on output power. A schematic of the Nd:YAG laser is shown in FIG. 2. The threshold and slope efficiency of this laser was 1 W of input pump power and 50%, respectively. It had a FWHM of 0.30 nm centered at 945.8 nm. The Nd:YAG solid state crystal laser utilized in the invention was obtained from InnoLight GmbH (Hannover, Germany) and the broad-area
10 semiconductor laser diodes were Polaroid POL-5100BW series brand laser diodes (Polaroid Corporation; Norwood, MA). The laser diodes were collimated in the fast axis by a μ -lens element with 100 μ m diameter. This reduced the fast axis NA from 0.6 to about 0.03. An image of the μ -lens aperture was made by a spherical lens element which had a focal length of 1.8 cm. The beams from each laser diode were spatially
15 overlapped in the polarization multiplexer and magnified X 1.5 by a lens element, which had a focal length of 2.7 cm. The focused pump spot radius ($1/e^2$) was approximately 80 ± 10 μ m. The measured laser beam spot radius at 100 mW output power was 80-100 μ m, corroborating good pump-signal overlap necessary for efficient quasi-four-level operation.

20 With a double-pass pump absorption using appropriate coatings in the Nd:YAG laser resonator, about 1.7 W at 946 nm can be achieved with the same 2X2W laser diode pumps. With 85% coupling of this 1.7 W output into the fiber and an 80% Yb laser slope efficiency, greater than 1.2 W @ 980 nm should be obtained.

The Yb doped fiber laser consisted of a length of Yb-doped fiber with 2 gratings
25 fusion spliced on each side of it as illustrated in FIG. 1. In the input side, pump power was coupled through a X10 aspheric lens element (Newfocus brand lens #5726) into Flexcore 1060 brand optical fiber (Corning Incorporated; Corning, NY) containing a 1030 nm long-period grating (LPG) which was spliced to CS980 brand optical fiber (Corning Incorporated; Corning, NY) containing a Bragg grating back reflector. In the
30 output side, Flexcore 1060 brand optical fiber (Corning Incorporated) containing a Bragg grating pump reflector was spliced to CS980 brand optical fiber (Corning Incorporated) containing a Bragg grating output coupler.

It was found that efficient pump absorption and exclusive three-level laser operation pull the required Yb fiber length in opposite directions; it was found that 946 nm pump absorption should be at most 4-5 dB at threshold, in order to avoid quasi-four-level oscillation in a fiber laser with 14 dB round-trip loss. Since low pump absorption was unacceptable, a spectral filter was used to increase pump absorption. The Yb-doped alumino-silicate fiber with length of 50 cm allowed $\approx 85\%$ absorption of pump power just below laser threshold; however, besides three-level oscillation between the $^2F_{5/2} \rightarrow ^2F_{7/2}$ manifolds at 978 nm, unwanted quasi-four-level lasing at 1030 nm and at 1012 nm between two other pairs of strong Stark levels of the same manifolds was simultaneously observed. This was eliminated by the LPG which had a 13 dB notch at 1027 nm; this grating had a loss of 0.15 dB at 946 nm and 1.2 dB at 1012 nm.

The back reflector was a 0.5 nm FWHM FBG centered at 979.8 nm with peak reflectivity $>99\%$. The pump reflector was a 0.6 nm FWHM FBG centered at 945.8 nm with peak reflectivity of $>99\%$; this grating allowed $\approx 97\%$ pump absorption in a double-pass; for the given fiber length, by taking the pump reflector out about 15% of pump power leaks from the fiber end; it was found that the pump reflector grating also helped to suppress unwanted oscillation at 1012 nm. The output coupler had a 0.5 nm FWHM centered at 979.9 nm with peak reflectivity of 5%; this grating maintained narrow-line oscillation at high pump powers. Without the output coupler, the fiber lased between its cleaved facets at high pump power. The Yb: SiO₂ fiber was 0.2 wt.% Yb and 0.2 wt. Al, NA=0.22, cut-off wavelength of 870 nm and peak absorption of 1.77 dB/cm at 980 nm with background loss of 8 dB/km.

The laser power measured from a cleaved facet of the output CS980 fiber end is shown in FIG. 4 vs. input pump power (measured before the Newfocus brand x10 aspheric lens element); black dots 401 represent result points and solid line 402 is a linear interpolation of these results. Threshold was approximately 41 mW of input pump power and the slope efficiency was 59 % with respect to input pump power. Measured losses were as follows: 1.0 dB fiber coupling loss (which corresponds to a coupling efficiency of 88% taking into account the lens 97% transmission and 7% Fresnel reflection from fiber facets), 0.25 dB splicing loss (for a total of 4 splices) and 0.15 dB LPG insertion loss, for a total of about 1.4 dB. After correcting for these

losses, the laser slope efficiency is 81% and laser threshold is 30 mW, both with respect to absorbed pump power. The spectrum at 655 mW output power is shown in FIG. 5; it has a FWHM of 0.15 nm centered at 979.8 nm.

A second alumino-silicate Yb-doped fiber was utilized in the invention, having 2.5 wt.% Yb and 8.3 wt.% Al, NA=0.26, cut-off wavelength of 940 nm and peak absorption of 9.75 dB/cm at 980 nm with background loss of 20 dB/km. A 9.5 cm length of this Yb-doped fiber allowed about 85% pump absorption, with measured threshold and slope efficiency of approximately 60 mW and 60%, with respect to absorbed pump power.

These alumino-silicate Yb-doped fibers were prepared by the method by MCVD (modified chemical vapor deposition) process. The results for measured slope efficiency and power threshold are summarized in Table 1. In each case, the Yb fiber length was optimized for lasing at 980 nm with 90% pump absorption, and splice losses were reduced to a minimum. These measurements were obtained with input LPG and back reflector in place, but no gratings in the output end in that the output reflector was the cleaved Yb fiber facet

TABLE 1.

Fiber	Composition (oxide wt.%)	Length for 90% pump absorp- tion (cm)	Pump power threshold (mW)	Slope efficienc y
Reference	0.06Yb	50	12	0.67
First Example	0.2Yb/0.2Al	60	28	0.79
Second Example	2.5Yb/8.3Al/0.5Ge	10	56	0.57

All of these fiber lasers contained two splices: one Flexcore to CS980 splice which consistently had a measured loss of <0.1 dB, and one CS980 to Yb fiber with estimated loss <0.2 . The numbers for slope efficiency and threshold were obtained by linear fit to measured input/output points and corrected for pump leakage, pump coupling and Flexcore-CS980 splice loss; they were not corrected for the less reproducible CS980-Yb fiber splice loss; thus, slope efficiency with respect to absorbed pump power may be up to 5% higher in these alumino-silicates.

FIG. 6 shows typical spectra observed without the output gratings (pump reflector and output coupler) for 300 mW of output power. Curve 601 shows how the spectrum breaks with only the LPG and back reflector FBG in place; about 92% of the laser power output is within the FBG bandwidth; weak spurious feedback causes the remaining 8% to be emitted near the peak of the $^2F_{5/2} \rightarrow ^2F_{7/2}$ transition at 978 nm. For comparison, the free-running spectrum (curve 602) and the spectrum obtained with the FBG replaced by a chirped FBG (curve 603) are also shown; the former has a FWHM of 3.3 nm centered at 978.0 nm, while the latter has a FWHM of 3.2 nm centered at 979.0 nm. The chirped FBG had reflectivity $> 98\%$ over 25 nm centered at 980.0 nm. Thus the use of proper gratings provided bandwidth control.

Example 3

The Nd doped solid state laser system was utilized to directly pump an Er doped L-Band optical amplifier to provide optical amplification in the 1560 to 1620 range. As shown in FIG.3, the Nd:YAG solid state laser output of about 1 watt at 946nm was directly coupled into a L-Band optical amplifier so that approximately 29 dBm of 946 nm light was inputted into a 200 meter length of Er doped optical amplifier fiber. The Er doped optical amplifier fiber was a silica fiber doped with Er and Al. This provided about 22dBm of amplified output power at 1585 nm with 8.9dBm of input power at 1585 nm. Er propagation loss of about 20dBm/km were estimated and the Er absorption at 940 nm was measured to be about 0.2dB/m.

It will be apparent to those skilled in the art that various modifications and variations can be made to the present invention without departing from the spirit and scope of the invention. Thus, it is intended that the present invention cover the

modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

What is claimed is:

1. An optical waveguide device comprised of:

a solid state laser for outputting an emission λ_{ss} centered about 946 nm, a lasing waveguide, said lasing waveguide comprising a Yb doped optical waveguide, said Yb doped optical waveguide having an input end and an output end, said input end is optically coupled to said solid state laser such that said emission λ_{ss} outputted from said solid state laser is inputted into said Yb doped optical waveguide input end and an emission λ_y centered about 980 nm is outputted from said Yb doped optical waveguide output end.

2. A method of producing a 980 nm pump light, said method comprising:

providing a first laser for producing an emission λ_1 , centered about 808 nm;

inputting said produced emission λ_1 , centered about 808 nm into a second laser for producing an emission λ_2 centered about 946 nm;

producing an emission λ_2 centered about 946 nm;

inputting said produced emission λ_2 centered about 946 nm into a third laser for producing an emission λ_3 centered about 980 nm;

producing an emission λ_3 centered about 980 nm.

3. An optical amplifier device comprised of:

a semiconductor laser which produces an emission λ_1 , centered about a first semiconductor wavelength;

a first solid state laser which is optically pumped by said semiconductor laser, said first solid state laser produces an emission λ_2 centered about a first solid state wavelength, said first solid state wavelength in the Yb absorption spectrum peak centered about 920 nm;

a second solid state laser which is optically pumped by said first solid state laser, said second solid state laser produces an emission λ_3 centered about 980 nm;

an optical amplifier for amplifying an optical transmission signal, said optical amplifier optically pumped by said second solid state laser.

4. A method of amplifying an optical transmission signal, said method comprising:

providing a first laser for producing λ_1 light;

providing a second laser for producing λ_2 light;

5 providing a third laser for producing λ_3 light;

providing an optical amplifier which utilizes λ_3 light to amplify an optical signal;

pumping said second laser with λ_1 light produced by said first laser;

pumping said third laser with λ_2 light produced by said second laser; and

10 pumping said optical amplifier with λ_3 light.

5. A method of making a 980 nm pump for an optical amplifier comprising:

providing at least one semiconductor laser diode;

coupling said semiconductor laser diode into a solid state laser;

15 coupling said solid state laser into a Yb doped optical fiber laser.

6. A method of making an optical amplifier pump, comprising the steps of:

providing a multimode pump source;

providing a single cladding optical waveguide lasing fiber; and

20 indirectly pumping said lasing fiber with said multimode pump source.

7. A method of amplifying an optical signal λ_s , comprising the steps of:

providing a multimode light pump source having a wavelength λ_{mm} multimode brightness output;

25 converting said multimode brightness output into a single mode output having a wavelength λ_{pump} ;

inputting said single mode output into an optical amplifier for amplifying an optical signal λ_s .

30

8. An optical amplifier pump for pumping an optical amplifier with a pump wavelength λ_{pump} ,

said pump including a semiconductor laser which produces a wavelength λ_{semi} ;

5 said pump outputting at least 500 mW of light at λ_{pump} .

9. An optical amplifier pump comprising:

a semiconductor laser which produces a wavelength λ_1 for pumping Nd ions;

10 a plurality of Nd ions, which when pumped by said wavelength λ_1 , produces a wavelength λ_2 for pumping Yb ions;

a plurality of Yb ions, which when pumped by said wavelength λ_2 produces a wavelength λ_3 for pumping Er ions.

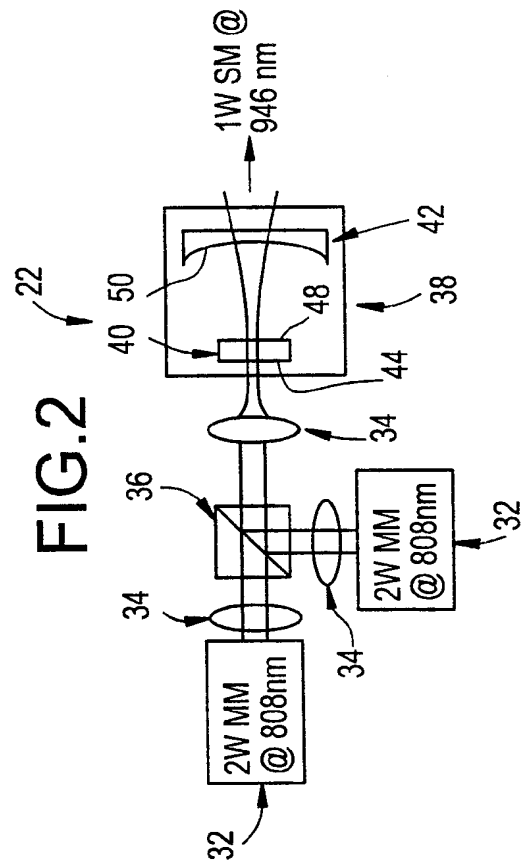
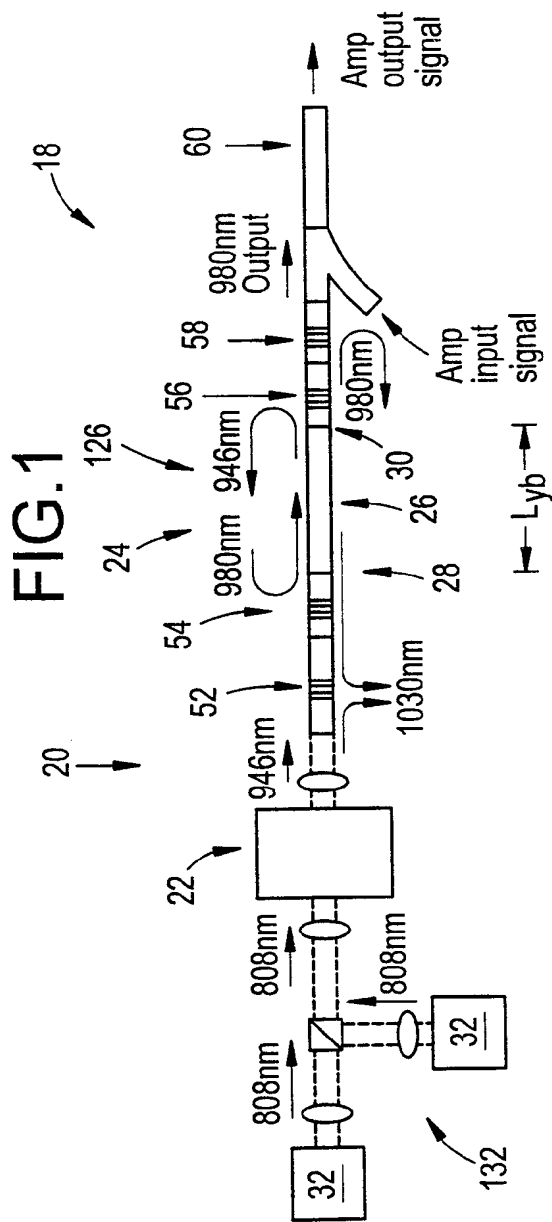
15 10. A method of amplifying a L-band optical signal comprising:

providing an Er doped optical fiber;

pumping a neodymium solid state laser with a broad area semiconductor laser;

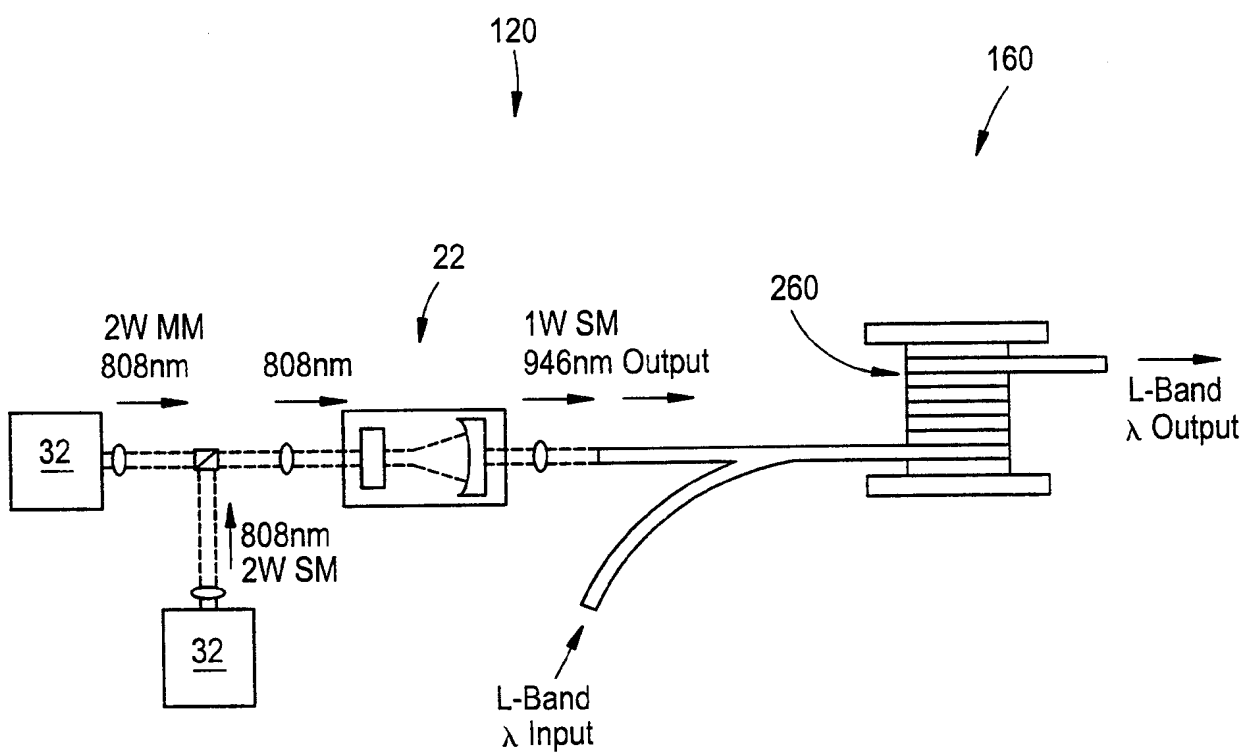
inputting said solid state laser into said Er doped optical fiber; and

20 amplifying a L-band optical signal with said Er doped optical fiber.



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FIG.3



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FIG.4

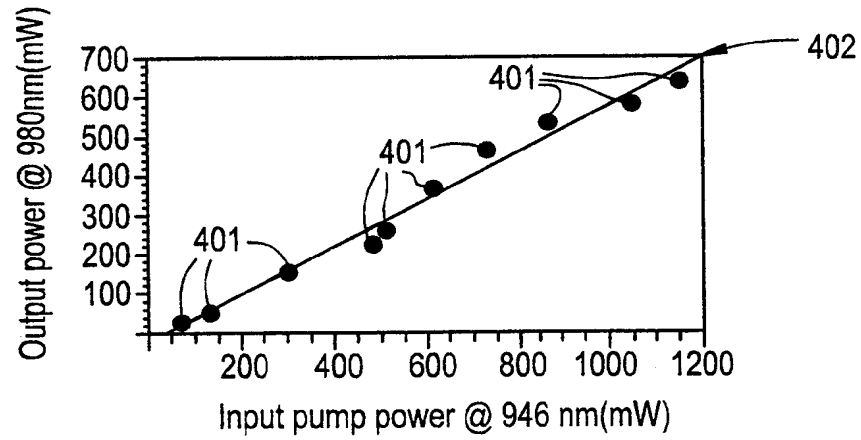


FIG.5

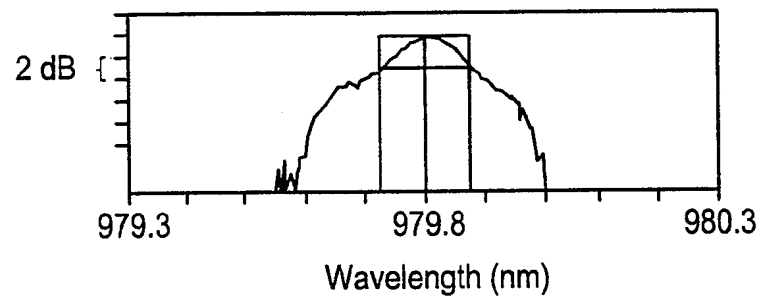
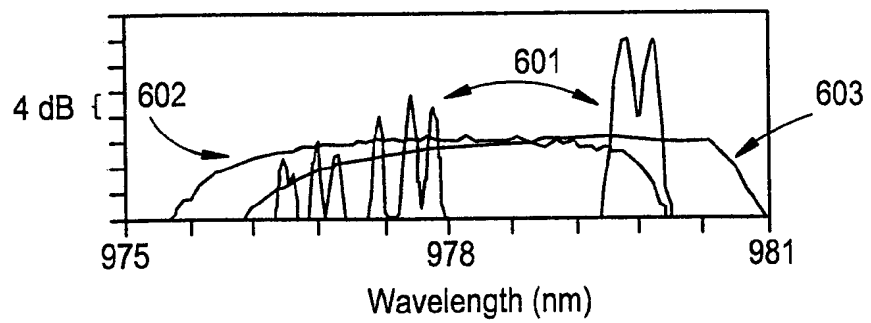


FIG.6



INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 99/29629

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 H01S3/067 H01S3/094 H01S3/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 H01S

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
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Date of the actual completion of the international search

18 April 2000

Date of mailing of the international search report

16/05/2000

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 99/29629

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

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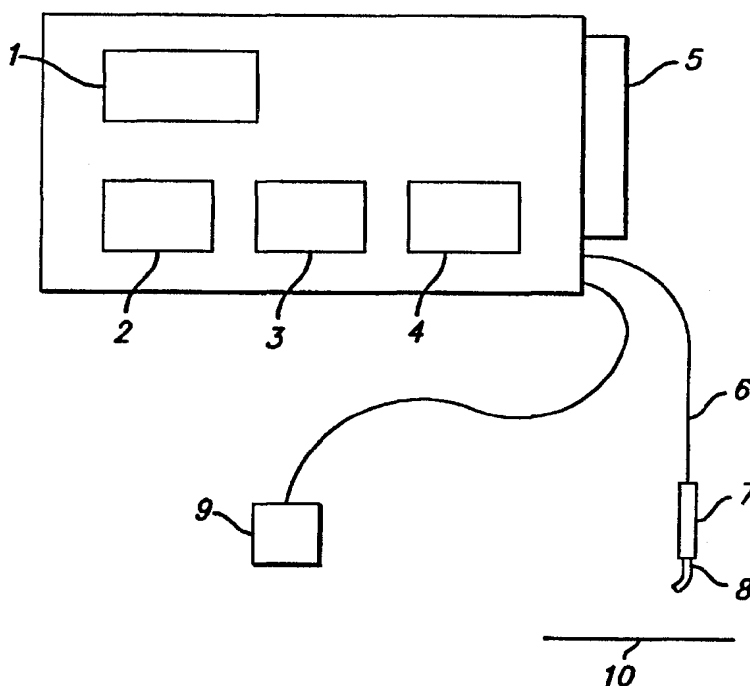
INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁷ : A61B 18/00		A1	(11) International Publication Number: WO 00/44294
			(43) International Publication Date: 3 August 2000 (03.08.00)
(21) International Application Number: PCT/US00/02136 (22) International Filing Date: 28 January 2000 (28.01.00) (30) Priority Data: 60/117,942 29 January 1999 (29.01.99) US (71) Applicant (for all designated States except US): WELCH AL- LYN, INC. [US/US]; 4341 State Street Road, Skaneateles Falls, NY 13153 (US). (72) Inventors; and (75) Inventors/Applicants (for US only): KUTSCH, V., Kim [US/US]; 1155 Twin Hills Drive, Jefferson, OR 97352 (US). McEACHERN, Richard, D. [US/US]; 1360 Dexter Road, Escondido, CA 92029 (US). (74) Agents: BRUEGGEMANN, James, R. et al.; Sheppard Mullin Richter & Hampton LLP, 333 South Hope Street, Los Angeles, CA 90071 (US).		(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG). Published <i>With international search report.</i>	

(54) Title: APPARATUS AND METHOD OF PHOTO-SPECIFIC TISSUE TREATMENT

(57) Abstract

An apparatus and related method are disclosed for directing a continuous or pulsed, polychromatic light beam through a hand-held light guide at a target biological tissue, as part of a health-related treatment in medicine or dentistry. The non-laser polychromatic light beam can be pulsed at a duration and duty cycle selected to provide optimal heating of the target issue, e.g., to temperatures in the range of 37° to 175 °C, while allowing the tissue to undergo a thermal relaxation response between successive pulses. The treatment delivers a photo-specific energy density in the range of 10 to 5000 watts/cm², selected to achieve the desired treatment. In the case of dental procedures on hard dental tissue, such treatments can include tooth bleaching, curing of dental composite materials, detecting of caries, cutting of enamel, dentin and bone, desensitizing of dentin, etching of enamel, osteoplasty, ostectomy, shade matching and other cosmetic procedures, trans-illumination, imaging and/or illumination.



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APPARATUS AND METHOD OF PHOTO-SPECIFIC TISSUE TREATMENT

BACKGROUND OF THE INVENTION

The present invention relates generally to the use of non-coherent
5 light in various health-related fields such as medicine, dentistry, and veterinary
medicine. More specifically, the invention relates to the use of pulsed light to
treat biological tissue.

Laser surgery is commonplace in modern dental practice. Reasons
for laser use include minimization of both trauma during surgery and post-
10 operative pain to the patient. Laser light has been used to stop bleeding, to cut
tissue, to weld, and to coagulate tissue. This light/tissue interaction can cause
non-specific photo-thermal changes that can result in reflection, absorption,
scattering, and transmission of the light by the tissue. Details can be found in a
reference entitled *Lasers in Dentistry*, by L.J. Miserendino and R.M. Pick,
15 Quintessence Books, 1995.

Lasers can function to concentrate high densities of light energy on
a very small spot. Very little of this light is diverged because of the coherent and
collimated nature of laser light.

Many patents have issued in the field of using laser light as a tool
20 in medical applications. Among these include ophthalmic treatments for macular
degeneration, retinal attachment, and cataract removal. Patents also have issued
relating to the use of laser light for hair removal, dermatology treatments, scar
removal, and facial rejuvenation.

As one example, U.S. Patent No. 5,435,724 to Goodman et al.
25 describes dental procedures and apparatus using pulsed ultraviolet light.

Specifically, ultraviolet light pulses are used to selectively etch both hard and soft tissue in dental procedures. Distinct ablation, or vaporization, thresholds exist for each type of tissue. This allows the dentist to perform both hard and soft tissue procedures without damaging healthy enamel, dentin, or the like.

5 Laser light has been widely applied in dentistry for soft tissue treatment and surgery. Laser light customarily is delivered via optical fibers, hollow waveguides, or articulated arms. Dental soft tissue treatment may include hemostasis, coagulation, ablation, and vaporization of soft oral tissue. Lasers have been used for periodontal treatment, gingiva surgery, frenum
10 surgery, and the like. In fact, laser treatment of maxillary midline frenectomy is becoming a standard of care. Post-operative pain is rare when lasers are used for this procedure.

 Medical, dental and veterinary procedures that use laser light function by raising tissue temperature. The table below indicates the effects on
15 tissue as a function of temperature and energy.

TABLE 1

<u>Tissue Effect</u> <u>(Watts/cm²)</u>	<u>Temp (degrees C)</u>	<u>Energy</u>
Hyperthermia	37-50	<10
20 Coagulation	50-60	100-500
Welding	70-80	500
Vaporization	90-100	500-1,000
Carbonization	100-150	1,000-5,000
Rapid Cutting	>175	>5,000

One advantage of laser soft tissue treatment is that the heat generated kills bacteria. It also provides a bloodless operating field, which results in less post-operative inflammation and pain.

5 Most laser procedures are contact, or near contact, surgeries, making the collimation feature not critical. In addition, laser light loses its coherent upon passage through a fiber optic. Since most dental lasers are delivered through fiber optics, the coherent characteristic is not necessary either. The important and necessary feature of the delivered light for medical, dental and veterinary procedures is its energy density.

10 In the past, conventional photo-thermal treatment of oral soft tissue has been accomplished using only certain approved lasers. These include visible light lasers such as argon and infrared lasers such as aluminum gallium arsenide diode, Nd:YAG, Ho:YAG, Er:YAG, and CO₂. These devices are very efficient in providing the desired photo-thermal effects on soft tissue.

15 According to dental and medical authorities, the advantages of using lasers, particularly CO₂ lasers, in oral surgery, include excellent hemostasis, improved viability during the procedure, minimal damage to adjacent tissue, reduced postoperative swelling, pain and infection, and a relative absence of scarring and wound contracture. These benefits have been attributed
20 to the ability of the CO₂ laser to seal small blood vessels and lymphatics, which circumvent some of the inflammatory processes of wound healing. The CO₂ laser was limited in its early use by its inability to be effective in hard tissue, namely bone, enamel, cementum, and dentin.

Further work to broaden the application of lasers led to the Nd:YAG lasers in the 1980's. Research continues to develop new uses for dental lasers, for hard tissue procedures as well as various restorative procedures. Some of the procedures may be caries detection and prevention, cutting enamel, dentin, and bone, desensitization of dentin, enamel etching, osteoplasty, and ostectomy.

One drawback of these laser tools is that they are quite expensive to purchase and maintain. Also, certain lasers equipped with articulating arms are often cumbersome. Specifically, CO₂ lasers with articulated arms are often difficult to use for dental procedures. Additionally, the CO₂ laser beam is invisible. A visible He:Ne laser beam can be built coaxially, for use as an aiming device. Aiming an invisible light at soft tissue from a distance is difficult and risks adjacent tissue of being inadvertently hit by the laser beam.

The fact that lasers are monochromatic is an inherent limitation, because tissue absorption profiles are polychromatic. Because of this discrepancy, lasers offer a less than optimum and limited range of applicability in many dental and medical procedures.

Many medical, dental, and veterinary laser procedures are contact, or near contact surgeries, making the collimation feature of laser light not critical. In addition, laser light loses its coherent upon passage through a fiber optic. Since most dental lasers are delivered through fiber optics, the coherent characteristic is not necessary either. The important and necessary feature of the delivered light for medical and dental procedures is its absorption by tissue. This absorption raises the tissue temperature and causes the tissue effect.

25

Since the absorption profile for all tissues is a broad band of wavelengths, the monochromatic feature of laser light is also not necessary. In fact, more efficient transfer of energy occurs over the entire bandwidth of the absorption profile of the tissue.

5 It should therefore be appreciated that there is a need for an improved apparatus and related method for treating biological tissue as effectively as some of the laser systems described above, but without the associated drawbacks. The present invention satisfies this need.

SUMMARY OF THE INVENTION

10 The present invention is embodied in an improved apparatus and related method for performing medical and/or dental procedures on a target biological tissue, with greater efficiency and without undue expense. The apparatus includes a light source for emitting a high-intensity light beam having an initial polychromatic spectrum, and a light guide having an inlet disposed at
15 an effective focal position of the light source and a handheld outlet end, of small cross-section, configured to be disposed in proximity to the biological tissue to be treated. A pulsing device also can be included, for pulsing the light beam emitted by the light guide for a selected duration and duty cycle, such that the biological tissue being treated undergoes a thermal relaxation response between
20 successive pulses. In addition, an optical filter can be included for tailoring the spectrum of the light beam directed to the target tissue for efficient interaction with the tissue.

In more detailed features of the invention, the apparatus further includes an adapter selectively attachable to the outlet end of the light guide, for
25 directing a portion of the light beam emitted by the light guide to the biological

tissue to be treated. This adapter can be configured to carry the optical filter. Further, the pulsing device can be configured to allow an operator to independently control both the duration and the duty cycle of the successive pulses of light emitted by the apparatus. This pulsing device preferably is
5 disposed between the light source and the light guide. The light guide preferably takes the form of an optical fiber assembly including a bundle of tightly packed optical fibers, with the inlet end of the optical fiber assembly having a diameter in the range of 1 to 2 mm.

In other more detailed features of the invention, the apparatus is
10 configured to be suitable for use in dental procedures on hard dental tissue, including tooth bleaching, curing of dental composite materials, detecting of caries, cutting of enamel, dentin and bone, desensitizing of dentin, etching of enamel, osteoplasty, ostectomy, shade matching and other cosmetic procedures, trans-illumination, imaging and/or illumination. In such applications, the light
15 source preferably is selected from the group consisting of halogen lamps, metal halide lamps, and plasma arc lamps, and it is configured to produce a light beam having a power level in the range of 12 to 500 watts. The polychromatic light beam directed to the biological tissue to be treated preferably has a power level of at least about 0.1 watt and includes wavelengths in the range of about 400 to
20 750 nm, and it has a photo-specific energy density in the range of 10 to 5000 watts/cm².

Other features and advantages of the present invention should become apparent from the following description of the preferred embodiment, taken in conjunction with the accompanying drawings, which illustrate, by way
25 of example, the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a simplified schematic drawing of a preferred embodiment of a photosurgery apparatus in accordance with the invention.

FIG. 2 is a more detailed diagram of the control panel portion of
5 the photosurgery apparatus of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

For the purposes of this description, the terms 'medical,' 'dental' and 'veterinary' are used interchangeably. Most of the examples will be for dental applications of the light apparatus, but it is to be understood that the soft
10 tissue treatments could be performed on any biological tissue.

The apparatus of the invention utilizes a special non-laser light source that is capable of delivering high power densities of a narrow wavelength distribution. The apparatus can perform contact or near contact treatment of tissue. The apparatus uses non-coherent visible light transmitted through a light
15 guide, e.g., an optical fiber assembly, a hollow or liquid-filled waveguide, or an articulated arm, to deliver sufficient light energy to the tissue to controllably increase the tissue temperature. As can be seen in the above table, the increased tissue temperature results in hyperthermia, coagulation, welding, vaporization, carbonization, or rapid cutting.

20 The light source preferably is configured to emit visible light having a plurality of wavelengths and combinations of wavelengths in the visible and near infrared regions. A preferred wavelength spectrum is in the range of

400-750 nm, and preferably centered at about 565 nm. A 100-500 micron filter delivering at least 0.1 watt of continuous or selectively pulsed light to the tissue.

The apparatus of the invention overcomes the drawbacks associated with lasers by providing an inexpensive and versatile alternative to achieve comparable photo-thermal treatment. In the present invention, metal halide lamps are used which exhibit larger arcs of light energy. To couple a significant amount of light energy into a single transmission fiber requires that the fiber be larger than 600 microns. A single fiber would be too stiff and/or fragile to be used in the desired applications of this invention. In this invention, other means are used to transmit large amounts of light energy to tissue.

The arc sizes of the metal halide lamps used in this invention are made by Welch Allyn, Inc., of Skaneateles Falls, New York, and can be easily coupled into fiber bundles between 1 mm and 2 mm in diameter. With lamp powers of between 12 watts and 500 watts, such lamps achieve efficiencies which can provide between 2 to 5 watts of power coupled into and transmitted through a fiber optic bundle. The wattage not transmitted through the fiber optic bundle is dissipated as heat.

Coupling large amounts of non-coherent energy through small single strand fiber optic cable is known. To maintain flexibility, such single fibers must be no larger than 600 microns, typically 400 microns. To accomplish this, the energy source must be a short-arc arc lamp, at power levels ranging from 12 to 500 Watts, with special large diameter focusing optics to couple the required amount of energy into the fiber. The resulting high-intensity beam can be directed by the fiber tip directly into or onto tissue to achieve rapid photo-coagulation.

In this invention, a fiber optic bundle, consisting of many individual small diameter fibers configured in a tightly packed optimal configuration at the ends, is used to transmit light energy. This results in a fiber optic bundle with diameters larger than 600 microns and extremely flexibility.

5 The end fibers are fused into solid entrance apertures of up to several inches in diameter, maintaining flexibility through the bulk of the length of the transmission cable and a relatively high transmission efficiency. Such a fiber bundle exhibits similar light transmission efficiencies as single fibers, with the exception of packing fraction losses. These losses are due to the cladding loss
10 at the fiber entrance and they can usually be limited to not more than 30 to 35 % of the total amount of light transmitted. The increased diameter of the entrance aperture and resulting increased coupling efficiency can more than make up for this loss.

The tip of the fiber optic assembly can be a bare fiber, a sculpted
15 tip, a tapered fiber optic bundle, a focusing handpiece, or a defocusing handpiece, depending on the spot size appropriate for the procedure to be performed. A defocused tip allows the light to spread out to a larger spot size. Focused light is used when contact surgery is being performed. Defocused light is used for illumination and for non-surgical procedures such as dental bleaching,
20 shade matching, and curing composite dental resins. The tip of the fiber optic assembly also can connect to a cannula, for convenient use in directing the light to selected portions of the target tissue.

In this invention, the larger exit diameters for the fiber conduits (up to 600 microns), handpieces which condense the transmitted light energy into
25 higher intensity spots are required. These handpieces may be disposable or removable to facilitate sterilization, and would consist of a lens or mirror which redirects the exiting light beam into a tightly focused spot. The lenses are either

discrete lenses spaced at an appropriate distance from the fiber exit to reduce the image size, or the end of the fiber optic cable can be figured into a focusing lens to produce the intense spot of light. Another possible approach for light delivery is to use a SelfocTM, or gradient index lens, attached at the end of the fiber optic bundle to produce the high-intensity spot at a distance from the end of the fiber. These approaches produce a high-intensity spot capable of performing dental, medical, and veterinary procedures on biological tissue with light at a distance of several millimeters to several inches from the fused fiber end of a lamp.

Yet another embodiment for delivering the light energy to the tissue includes a handpiece attached to a fiberoptic bundle, wherein the handpiece delivers the light through a focusing lens into a small cannula or hollow waveguide or sculptured sapphire tip, all of which could be used in or out of contact with the target tissue. The tips or cannulas could be detachable, autoclaveable or disposable. This embodiment could be used in contact with the tissue, or even in a procedure below the gingival tissue in the sulcus to treat periodontal disease and the like.

As can be seen from Figure 1, the apparatus of this invention is enclosed in a housing, which is preferably made of a combination of metal and injection molded plastic. The power supply 1 is internal, and may be either 110 or 220 volts. The light source 2, may be visible light such as halogen, metal halide, plasma arc or the like with an output of 12 to 500 watts. Multiple light sources are also considered to be within the scope of the present invention.

A pulse device 3 is configured to grate or optically chop the light beam emitted by the light source 2, to cause a strobe of the emitted light. The pulse device controls both pulse duration and duty cycle. Pulsing allows the treatment of tissue without anesthetic, which benefits both the doctor and the

patient. The light pulses raise the tissue temperature, and the interruptions allow the tissue to have a thermal relaxation response.

A filter 4 filters different portions of the visible spectrum of the light emitted by the light source 2. For example, the visible blue range (400-500 nm) is effective for photopolymerization, and the visible green range (480 –590 nm) is effective for surgical procedures. The filter can include a series of wavelength-specific filters that are actuated by a solenoid (not shown) to move them into the optical path. The filtering also can also be accomplished by either a filter or an optical coating on either end of the fiber optic delivery guide for each individual application. In addition, there may be multiple outlet ports, as well as multiple configurations of application-specific fiber optic guides, handpieces, and cannulas.

A control panel 5 allows an operator to control the apparatus using either a foot switch 9 or a finger control (not shown) in the handpiece 7. Remote control also is an option. The apparatus can operate as a stand-alone unit or it can be integrated into multiple operatories. The apparatus also can be integrated into traditional dental control units or into a high-tech accessory dental unit. In addition, the apparatus can be controlled by a separate foot pedal, or a foot pedal connected to a dental chair or a switch in the handpiece of the dental instrument.

The pulsed light beam generated by the apparatus of this invention is delivered to the tissue 10 through the optical fiber assembly 6, the handpiece 7, and the cannula 8.

Figure 2 shows a detailed view of the control panel 5. Control switches are provided, including a switch 21 to control the power selection, a switch 22 to control the selection of pulsing or continuous operation, and a

switch 23 to control the selection of color. The color selection switch selects the portion of the visible light spectrum that the operator desires to use, such as the wavelength range for blue light (400-500 nm) or for green light (480-590 nm), as discussed above.

5 The apparatus has multiple outlet ports 26, which allow the apparatus to be used for soft tissue surgery, photopolymerization, bleaching, illumination, caries detection, and shade matching for cosmetic dentistry. This feature allows the operator to perform two or more operations simultaneously.

10 A reflector (not shown) that is part of the light source 2 has a focal point that either is in the longitudinal axis or is off-axis to the hot spot of the bulb. The hot spot is a section of the bulb (filament or arc) in which the maximum brightness occurs. This is substantially brighter than other sections of the light source. The bulb preferably is positioned so that this hot spot is coincident with the reflector's focal point.

15 The patient contact tool (i.e., the handpiece 7 and the cannula 8) may be detached from the optical fiber assembly 6 and sterilized in an autoclave, whereas the fiber optic guide may be autoclavable or disposable.

20 A microprocessor (not shown) controls the apparatus' various operating parameters, based on inputs from the control switches, etc. In addition, the microprocessor can select pre-set operating parameters and automatic default settings for specific applications, as desired by a user.

 The microprocessor also may be coupled to one or more remote microprocessors, to allow the tool to be controlled at a site remote from the patient.

Although the invention has been described in detail with reference only to the presently preferred embodiment, those skilled in the art will appreciate that various modifications can be made without departing from the invention. Accordingly, the invention is defined only by the following claims.

What is claimed is

1. A method for performing medical and/or dental procedures on a target biological tissue, comprising:

aiming a high-intensity, polychromatic light beam onto the target biological tissue, to heat the tissue and induce a photo-thermal effect therein; and

5 pulsing the light beam for a selected duration and duty cycle, such that the tissue undergoes a thermal relaxation response between successive pulses.

2. A method as defined in claim 1, wherein aiming comprises directing the light beam through a light guide having an outlet end disposed adjacent to the target biological tissue.

3. A method as defined in claim 2, wherein pulsing includes periodically interrupting the light beam prior to its being directed through a light guide in directing.

4. A method as defined in claim 1, and further comprising:
generating a light beam having an initial polychromatic spectrum;
and

5 filtering the light beam to remove a portion of its initial polychromatic spectrum prior to aiming.

5. A method as defined in claim 1, wherein the method is effective as a dental procedure on hard dental tissue, including tooth bleaching, curing of dental composite materials, detecting of caries, cutting of enamel, dentin and bone, desensitizing of dentin, etching of enamel, osteoplasty,

5 ostectomy, shade matching and other cosmetic procedures, trans-illumination, imaging and/or illumination.

6. A method as defined in claim 1, wherein the method delivers sufficient energy to the target biological tissue to raise the tissue to a temperature in the range of 37° to 175° C.

7. A method as defined in claim 5, wherein the polychromatic light beam aimed at the target biological tissue has a power level of at least about 0.1 watt and includes wavelengths in the range of about 400 to 750 nm.

8. A method as defined in claim 7, wherein the light beam aimed at the target biological tissue has a photo-specific energy density in the range of 10 to 5000 watts/cm².

9. A method as defined in claim 1, wherein:
the method is effective as a dental procedure on soft biological tissue; and

5 the light beam aimed at the target biological tissue has a photo-specific energy density sufficient to cause hyperthermia, coagulation, welding, vaporization, carbonization, and/or rapid cutting.

10. Apparatus for use in treating biological tissue, comprising:
a light source for emitting a high-intensity light beam having an initial polychromatic spectrum, wherein the light source directs the light beam to an effective focal position;

5 a light guide having an inlet end disposed at the effective focal position of the light source and further having a handheld outlet end, of small

cross-section, configured to be disposed in proximity to the biological tissue to be treated.

11. Apparatus as defined in claim 10, and further comprising:
a pulsing device for pulsing the light beam emitted by the light
guide for a selected duration and duty cycle, such that the biological tissue being
treated undergoes a thermal relaxation response between successive pulses; and
5 a filter for removing a portion of the initial polychromatic spectrum
of the light beam.

12. Apparatus as defined in claim 11, and further comprising an
adapter selectively attachable to the outlet end of the light guide, for directing a
portion of the light beam emitted by the light guide to the biological tissue to be
treated.

13. Apparatus as defined in claim 12, wherein the filter is
carried by the adapter.

14. Apparatus as defined in claim 11, wherein the pulsing
device is configured to allow an operator to independently control both the
duration and the duty cycle of the successive pulses of light emitted by the
apparatus.

15. Apparatus as defined in claim 11, wherein the pulsing
device is disposed between the light source and the light guide.

16. Apparatus as defined in claim 10, wherein the apparatus is
configured to be suitable for use in dental procedures on hard dental tissue,
including tooth bleaching, curing of dental composite materials, detecting of

5 caries, cutting of enamel, dentin and bone, desensitizing of dentin, etching of enamel, osteoplasty, ostectomy, shade matching and other cosmetic procedures, trans-illumination, imaging and/or illumination.

17. Apparatus as defined in claim 16, wherein the light source is selected from the group consisting of halogen lamps, metal halide lamps, and plasma arc lamps.

18. Apparatus as defined in claim 16, wherein the light source is configured to produce a light beam having a power level in the range of 12 to 500 watts.

19. Apparatus as defined in claim 16, wherein the polychromatic light beam directed to the biological tissue to be treated has a power level of at least about 0.1 watt and includes wavelengths in the range of about 400 to 750 nm.

20. Apparatus as defined in claim 19, wherein the polychromatic light beam directed to the biological tissue to be treated has a photo-specific energy density in the range of 10 to 5000 watts/cm².

21. Apparatus as defined in claim 10, wherein the light guide comprises an optical fiber assembly.

22. Apparatus as defined in claim 21, wherein:
the optical fiber assembly includes a bundle of tightly packed optical fibers; and

5 the inlet end of the optical fiber assembly has a diameter in the range of 1 to 2 mm.

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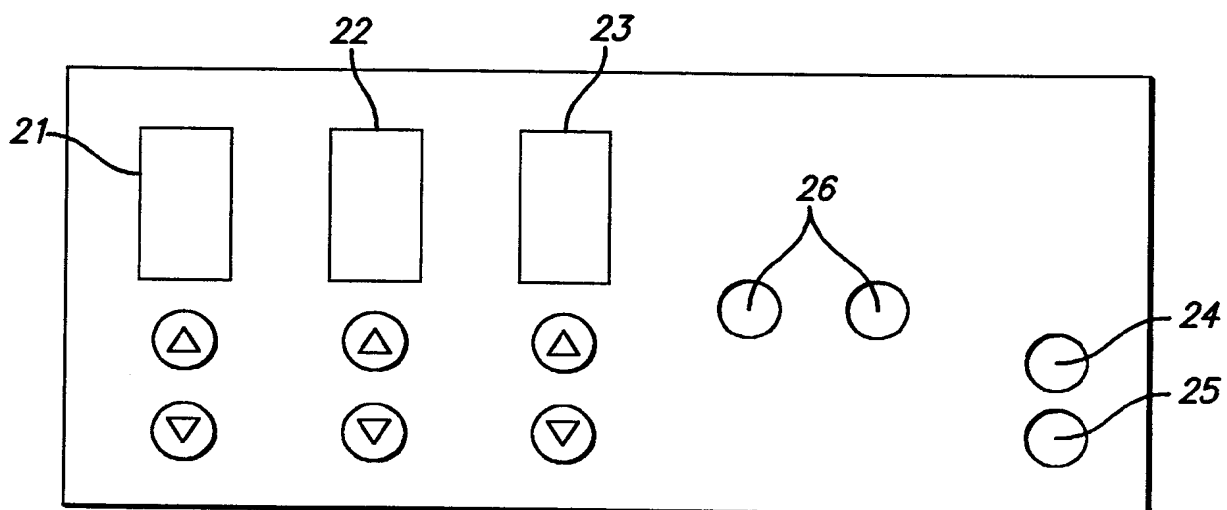
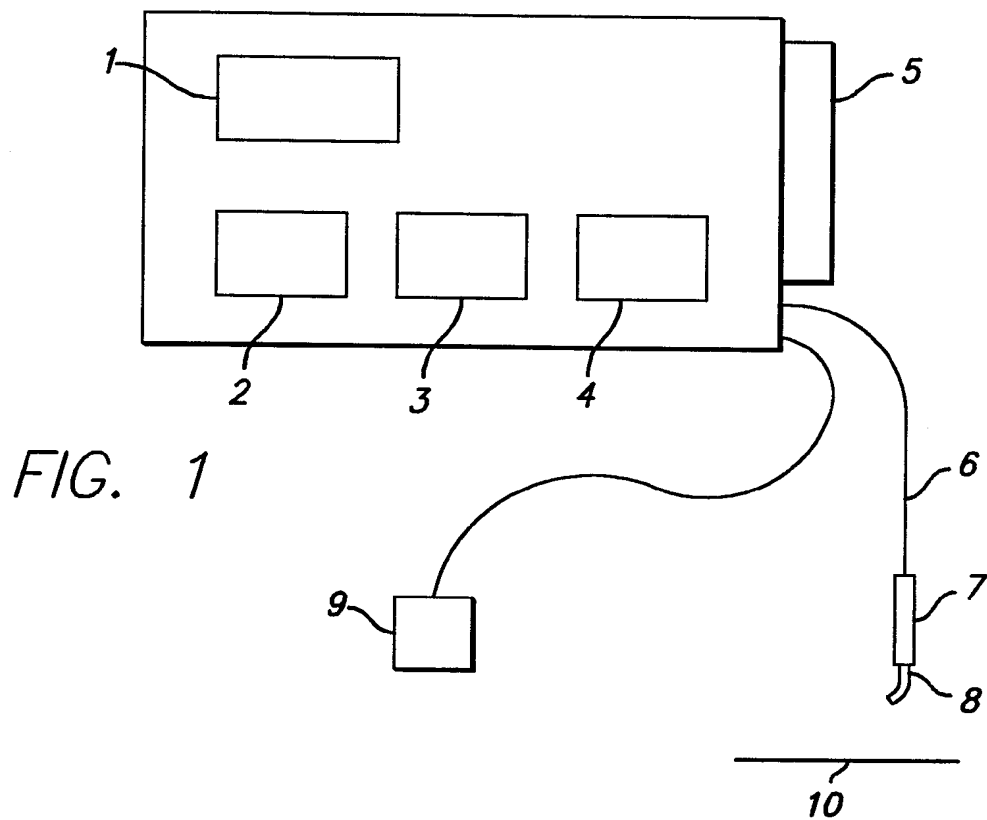


FIG. 2

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 00/02136

A. CLASSIFICATION OF SUBJECT MATTER IPC 7 A61B18/00		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) IPC 7 A61B G02B		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practical, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 860 172 A (SCHLAGER KENNETH J ET AL) 22 August 1989 (1989-08-22) column 4, line 15 - line 40; figure 1	10-21
X	WO 93 00551 A (GHAFFARI SHAHRIAR) 7 January 1993 (1993-01-07) page 15, line 8 - line 23; claims 1,5; figures 1,5	10-13, 16-21 14,15
A	US 3 327 712 A (KAUFMAN I H ET AL) 27 June 1967 (1967-06-27) column 2, line 65 - column 3, line 6 column 3, line 64 - line 68; figure 1	10,16, 17,19-22
X	US 4 852 549 A (MORI KEI) 1 August 1989 (1989-08-01) column 3, line 16 - line 19; figure 2	16
A		
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Date of the actual completion of the international search		Date of mailing of the international search report
12 May 2000		19/05/2000
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016		Authorized officer Mayer, E

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 00/02136

Box I Observations where certain claims were found unsearchable (Continuation of Item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.: 1-9
because they relate to subject matter not required to be searched by this Authority, namely:
Rule 39.1(iv) PCT - Method for treatment of the human or animal body by therapy
2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of Item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

information on patent family members

International Application No

PCT/US 00/02136

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4860172 A	22-08-1989	NONE	
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(WO/2000/054649) DEVICE FOR THE THERAPEUTIC AND COSMETIC PHOTO-PROCESSING OF BIOLOGICAL TISSUES AND METHOD FOR USING THE SAME

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Title: DEVICE FOR THE THERAPEUTIC AND COSMETIC PHOTO-PROCESSING OF BIOLOGICAL TISSUES AND METHOD FOR USING THE SAME

Abstract: The present invention relates to a method and an apparatus for permanently or temporarily removing human hair, for miniaturising the same or for changing the colour thereof. This apparatus can also be used for coagulating blood vessels, veins or a selective injury of the derma collagen in order to regenerate the same. This apparatus uses one or more incandescent lamps (4) in which the radiation spectrum (34) can be modulated in order to heat slowly and efficiently the derma (17) and in order to heat locally the hair follicles (35). This apparatus also includes an optical system that converts the blue-green portion on the spectrum of the incandescent lamps (4) into a red region of the spectrum, that provides a highly efficient concentration of converted radiation from the incandescent filament (37) of the lamps (4) on the area of biological tissues to be treated, and that ensures a repeated recirculation towards the skin (17) of the radiation scattered by the same.

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МЕЖДУНАРОДНАЯ ЗАЯВКА, ОПУБЛИКОВАННАЯ В СООТВЕТСТВИИ С
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(21) Номер международной заявки: PCT/RU00/00088 (22) Дата международной подачи: 17 марта 2000 (17.03.00) (30) Данные о приоритете: 99105549 18 марта 1999 (18.03.99) RU (71) Заявитель (для всех указанных государств, кроме (US): ЗАКРЫТОЕ АКЦИОНЕРНОЕ ОБЩЕСТВО «LS» [RU/RU]; 193036 Санкт-Петербург, ул. Восстания, д. 15 (RU) [ZAKRYTOE AKTSIONERNOE OVSCHE- STVO «LS», St.Petersburg (RU)]. (72) Изобретатели; и (75) Изобретатели/Заявители (только для (US): АКОПОВ Леонид Иванович [RU/RU]; 197198 Санкт-Петербург, ул. Колпинская, д. 7, кв. 6 (RU) [AKOPOV, Leonid Ivanovich, St.Petersburg (RU)]. БЕЛИКОВ Андрей Вячеславович [RU/RU]; 198217 Санкт-Петербург, пр. Народного Ополчения, д. 141, кв. 86 (RU) [BELIKOV, Andrei Vyacheslavovich, St.Petersburg (RU)]. БИРЮ- ЧИНСКИЙ Сергей Борисович [RU/RU]; 196135 Санкт-Петербург, Московский пр., д. 200, корп. 4, кв. 94 (RU) [BIRJUCHINSKY, Sergei Borisovich, St.Peters- burg (RU)]. ИНОЧКИН Михаил Владимирович [RU/ RU]; 197198 Санкт-Петербург, Кронверкский пр., д. 73, кв. 29 (RU) [INOCKIN, Mikail Vladimirovich, St.Petersburg (RU)].		(74) Общий представитель: АКОПОВ Леонид Иванович; 190000 Санкт-Петербург, ул. Колпинская, д.7, кв. 6 (RU) [AKOPOV, Leonid Ivanovich, St.Petersburg (RU)]. (81) Указанные государства: AT, AU, BR, CA, CH, CN, CZ, DE, DK, ES, FI, GB, HU, JP, KR, MX, NO, NZ, PL, PT, SE, SI, US, европейский патент (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE). Опубликована <i>Без отчёта о международном поиске и с повторной публикацией по получении отчёта.</i>
(54) Title: DEVICE FOR THE THERAPEUTIC AND COSMETIC PHOTO-PROCESSING OF BIOLOGICAL TISSUES AND METHOD FOR USING THE SAME (54) Название изобретения: УСТРОЙСТВО ДЛЯ ТЕРАПЕВТИЧЕСКОЙ И КОСМЕТОЛОГИЧЕСКОЙ ФОТООБРАБОТКИ БИОТКАНИ И СПОСОБ ЕГО ИСПОЛЬЗОВАНИЯ (57) Abstract <p>The present invention relates to a method and an apparatus for permanently or temporarily removing human hair, for miniaturising the same or for changing the colour thereof. This apparatus can also be used for coagulating blood vessels, veins or a selective injury of the derma collagen in order to regenerate the same. This apparatus uses one or more incandescent lamps (4) in which the radiation spectrum (34) can be modulated in order to heat slowly and efficiently the derma (17) and in order to heat locally the hair follicles (35). This apparatus also includes an optical system that converts the blue-green portion on the spectrum of the incandescent lamps (4) into a red region of the spectrum, that provides a highly efficient concentration of converted radiation from the incandescent filament (37) of the lamps (4) on the area of biological tissues to be treated, and that ensures a repeated recirculation towards the skin (17) of the radiation scattered by the same.</p>		

Предлагается прибор и процесс для постоянного и временного удаления человеческих волос, их миниатюризации и изменения цвета. Прибор может использоваться также для коагуляции кровяных сосудов, вен и селективного повреждения коллагена дермиса с целью его регенерации. В приборе используется одна или несколько ламп накаливания (4) с модуляцией спектра излучения (34), обеспечивающего эффективный мягкий нагрев дермиса (17) и локальный нагрев волосяной фолликулы (35). Прибор содержит оптическую систему обеспечивающую преобразование сине-зеленой части спектра лампы накаливания (4) в красную область спектра, а также высокоэффективную концентрацию преобразованного излучения нити накала (37) ламп (4) на обрабатываемую область биоткани (17) и многократную циркуляцию излучения рассеянного от кожи (17) обратно в кожу (17).

ИСКЛЮЧИТЕЛЬНО ДЛЯ ЦЕЛЕЙ ИНФОРМАЦИИ

Коды, используемые для обозначения стран-членов РСТ на титульных листах брошюр, в которых публикуются международные заявки в соответствии с РСТ.

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Устройство для терапевтической и косметологической фотообработки биотканей и способ его использования

Область техники

- Изобретение относится к медицинской технике и может применяться в дерматологии для постоянного и временного удаления человеческих волос, их миниатюризации и изменения цвета, а также для коагуляции кровеносных сосудов и селективного повреждения коллагена и подкожного жира.

Предшествующий уровень техники

- Известны устройства фотообработки биотканей, работа которых основана на селективном нагреве желаемой области биоткани (кожи, кровеносного сосуда или волосяной фолликулы). В качестве источника излучения в этих устройствах используются лазеры или дуговые лампы.

- В основном для селективного нагрева используются лазерные источники света. Это связано с тем, что лазер обеспечивает наилучшую спектральную селективность. Кроме того лазер, позволяет получить любую длительность импульса вплоть до нескольких фемтосекунд, и тем самым, обеспечить селективный нагрев биологических структур любых размеров. Излучение лазера легко фокусируется в малый объем. Это позволяет достичь желаемого уровня плотности энергии, а также обеспечить высокую эффективность ввода излучения в оптическое волокно и доставку его к операционному полю. В то же время лазер является самым дорогостоящим источником света и обладает повышенной опасностью прежде всего для зрения пользователя.

- Для ряда применений возможности селективного лазерного нагрева не являются необходимыми и могут быть осуществлены некогерентными источниками, например, лампой. При этом, для спектральной селекции используется поглощающий или флуоресцентный фильтр. В патенте США №3,327,712 предложено использовать дуговую лампу, с фильтром в области 300-600нм и доставкой излучения по жгуту волокон, для коагуляции тканей, а в патенте США №4,298,005 - устройство содержащее дуговую лампу, отражатель и спектральный фильтр в диапазоне 320-450 нм для косметологических применений. Это устройство не требует волоконной доставки излучения.

- В патенте США №5,320,618 описано устройство, в котором для селекции излучения дуговой лампы используется флуоресцентный фильтр. Флуоресцентный фильтр поглощает энергию коротковолновой части спектра лампы, которая не воздействует на мишень и переизлучает ее в длинноволновую область, для которой поглощение мишени имеет значительную величину. В патенте США №3,693,623 впервые предложено использовать дуговую лампу с зеленым фильтром и доставкой излучения по оптическому волокну для удаления единичного волоса путем коагуляции кровеносных сосудов в папилле.

Общий недостаток приведенных выше патентов состоит в том, что описанные в них устройства содержат дуговую лампу,

которая вообще говоря, дешевле и проще лазера, однако требует высоковольтных сильноточных источников питания и не может эксплуатироваться в домашних условиях или в косметических салонах. Кроме того, прибор на основе дуговой лампы имеет
5 весьма низкую эффективность. Это связано с тем, что эффективность преобразования электрической энергии в них в свет не превышает 60%, а плотность мощности на внешней поверхности плазменного столба из-за малого коэффициента "черноты" имеет
10 небольшую величину, что ограничивает максимальный поток, падающий на поверхность кожи.

Для создания максимально дешевых фотоэпиляторов и фотокосметических приборов в настоящее время наиболее подходящим источником света является лампа накаливания. Лампа накаливания может питаться безопасными для человека
15 источниками с низким напряжением, а эффективность преобразования электрической энергии в световую у лампы накаливания выше, чем у дуговых ламп (0,85 и 0,6 соответственно). Спектральная эффективность лампы накаливания для синего и зеленого диапазона ниже чем у дуговой из-за ограниченной
20 температуры нити ($< 3800^{\circ}\text{K}$), однако в диапазоне длин волн, в котором наиболее эффективно повреждается волос (больше 600нм) спектральная эффективность не уступает эффективности дуговых ламп с той же цветовой температурой. Плотность энергии на поверхности нити накала выше чем на поверхности плазменного
25 столба, что позволяет достичь большей плотности энергии на поверхности кожи. Лампа накаливания в отличие от дуговой лампы не может эффективно излучать импульсы короче 50мс, что обычно необходимо для селективного нагрева области волосяного столба или папиллы в особенности для тонких волос или тонкого слоя
30 дермиса, подкожного жира или кровеносных сосудов. Поэтому для создания дешевого и безопасного прибора для удаления волос на основе лампы накаливания необходимо обеспечить дополнительные приемы повышения эффективности воздействия, что и является предметом настоящего изобретения.

35 Наиболее близким к предлагаемому устройству и выбранным в качестве прототипа является устройство для коагуляции кровеносных сосудов (Пат. США №4.539.987 опубликован 10.09.1985г.).

40 Это устройство содержит источник электромагнитного излучения в виде лампы накаливания, рефлектор для концентрации излучения на обрабатываемую область биоткани, при этом между лампой накаливания и обрабатываемой биотканью помещен кристаллический диэлектрик прозрачный для излучения и находящийся в контакте с обрабатываемой биотканью. Этот
45 кристаллический элемент, соединенный с системой охлаждения или теплоемкой массой, предназначен для отвода тепла от приповерхностного слоя кожи. Между лампой и прозрачным диэлектриком может быть помещен поглощающий фильтр, пропускающий излучение в области 600-1400нм. В устройстве

используется лампа накаливания с электрической мощностью более 15Вт, с плотностью мощности на поверхности обрабатываемой биоткани более 10Вт/см². Рекомендуемая в этом патенте плотность мощности составляет 150Вт/см², для чего

5 предполагается в устройстве использовать лампу накаливания с максимальной электрической мощностью порядка 400 Вт, которая работает в обычном непрерывном режиме с временем воздействия около 2 сек. Коагуляция кровеносных сосудов осуществляется главным образом за счет поглощения излучения лампы водой,

10 содержащейся в коже.

Недостатком этого устройства является непригодность для эффективного локального нагрева волоса или мелкого кровеносного сосуда, тонкого слоя дермиса или подкожного жира. Действительно, как показано в патенте США №5735844 опубл.

15 07.04.1998г., для поражения волоса необходимо излучение с длиной волны от 600÷1100нм, с плотностью энергии не менее 10Дж/см² при длительности импульса 1-20 мс. Таким образом плотность мощности в этом диапазоне должна быть не менее 500Вт/см², что значительно выше, чем может быть получено с

20 использованием лампы накаливания с максимальной электрической мощностью 400Вт в непрерывном режиме, при диаметре освещенной зоны на поверхности биоткани 25 мм. Заметим, что номинальная мощность 400Вт является практическим пределом для миниатюрных галогенных ламп, излучение которых может быть

25 сконцентрировано на небольшой (Ø10-25 мм) площадке. При этих условиях световая мощность в области спектра 600-1400нм на поверхности биоткани не будет превышать 150 Вт (полная световая эффективность 0.8, эффективность осветителя 0.8, доля светового излучения в области 600-1400 нм - 0.6: $0.8 \cdot 0.8 \cdot 0.6 = 0.4$), а

30 плотность мощности - 40Вт/см², что опять таки значительно ниже необходимых 500Вт/см². Обратным расчетом легко убедиться, что необходимая мощность лампы должна составлять более 6кВт.

Наиболее близким к предлагаемому способу использования заявляемого устройства, и принятым в качестве прототипа,

35 является способ удаления волос, описанный в вышеупомянутом патенте (см. Патент США №5735844 опубл. 07.04.1998г.). В этом способе используются короткие световые импульсы длительностью от 2 до 100 мс с частотой следования 1 Гц и длиной волны в диапазоне от 680 до 1200нм в сочетании с охлаждением

40 эпидермиса. Сущность прототипа состоит в том, что в указанном диапазоне длин волн меланин, содержащийся преимущественно в матриксе клеток волосяной фолликулы и стволе волоса, обладает более высоким поглощением чем все остальные компоненты кожи. Поэтому возможен селективный нагрев волосяной фолликулы и

45 поражение ее органов ответственных за рост волоса: матрикса клеток в области папиллы и стим-клеток в области ствола волоса. Так как меланин содержится также на границе дермиса и эпидермиса, то при поражении фолликулы возможно одновременное поражение эпидермиса, например его отслоение.

Для предотвращения поражения эпидермиса в этом способе используется предварительное и одновременное со световым воздействием охлаждение эпидермиса. Способ удаления волос, описанный в этом патенте, предназначен для одновременной обработки одним световым импульсом нескольких волосяных фолликул. Плотность энергии оптических импульсов лежит в пределах от 10 до 200 Дж/см², и предполагается использование любых импульсных источников электромагнитного излучения, включая лазеры и некогерентные источники, с указанными выше параметрами.

Недостатком прототипа способа является недостаточная эффективность использования электромагнитной энергии при обработке из-за неоптимального режима воздействия на биоткань оптических импульсов с высокой плотностью энергии.

Раскрытие изобретения

Задачей, на решение которой направлено предлагаемое изобретение, является удешевление устройства с одновременным повышением эффективности и безопасности поражения волосяной фолликулы для перманентного ее повреждения или задержки роста, миниатюризации или осветления волоса, а также коагуляции кровеносных сосудов и селективного повреждения коллагена кожи или подкожного жира.

Данная задача решается за счет достижения технического результата, заключающегося в оптимальном использовании свойств обрабатываемой биоткани, заключающемся в изменении ее состояния в зависимости от времени, энергии и спектра воздействующего излучения.

Для достижения указанного технического результата лампа накаливания, которая является источником электромагнитного излучения в предлагаемом устройстве соединена с блоком питания через модулятор. Этот модулятор содержит измеритель сопротивления нити накала лампы и регулятор мощности, что позволяет обеспечить оптимальный режим обработки биотканей. Внутренняя поверхность рефлектора, предназначенного для концентрации излучения лампы на биоткань, выполнена зеркальной с функцией возврата излучения, отраженного от обрабатываемой биоткани, обратно в биоткань. Это позволяет значительно повысить эффективность функционирования устройства.

В контакте с обрабатываемой тканью при работе устройства находится охлаждаемая диэлектрическая призма, представляющая собой волновод. С целью обеспечения дополнительной безопасности обработки к этой диэлектрической призме вплотную присоединена металлическая пластина, которая также находится в контакте с обрабатываемой тканью и соединена с системой охлаждения. При этом при обработке ткани устройство перемещается так, что необлученный участок кожи сначала соприкасается с металлической пластиной, а затем с диэлектриком.

В устройстве предусмотрен также спектральный фильтр, поглощающий вредное для биоткани излучение, который с

диэлектрическим элементом образует оптический волновод. Это, в сочетании со сферической внутренней поверхностью рефлектора и конической боковой его поверхностью обеспечивает возврат излучения, отраженного от биоткани, обратно в биоткань.

5 Дополнительно, внутренне пространство рефлектора может быть снабжено системой воздушного охлаждения.

Кроме отдельного спектрального фильтра баллон лампы накаливания, зеркальное покрытие внутренней поверхности рефлектора, могут быть выполнены с функцией люминесцентного

10 спектрального преобразователя.

Бытовой вариант предлагаемого устройства для, например, удаления волос в домашних условиях может быть выполнен в виде "щипцов", захватывающих фрагмент кожи с волосяной фолликулой с учетом концентрации излучения на них в сомкнутом состоянии щипцов. Профессиональный вариант предлагаемого устройства

15 может быть выполнен с использованием нескольких миниатюрных ламп с напряжением питания ниже 40В. Бытовой вариант предлагаемого устройства может содержать одну миниатюрную лампу с напряжением питания до 40В.

20 Способы использования предлагаемого устройства для обработки различных биотканей отличаются временем воздействия, спектральным диапазоном и временем облучения. Причем предварительно происходит охлаждение обрабатываемой поверхности, а затем облучение в две фазы. Исключением является

25 случай повреждения коллагена дермиса с целью стимуляции его регенерации или повреждения слоя подкожного жира.

В предлагаемом устройстве используются лампы накаливания и модулятор тока или напряжения, который изменяет спектр излучения

30 лампы во времени так, что вначале воздействия света на кожу (первая фаза - преднагрев) максимум излучения сосредоточен в ближнем ИК диапазоне, а в конце воздействия он смещается в красную область спектра (вторая фаза - поражение). На первой фазе происходит нагрев дермиса за счет поглощения излучения

35 водой, содержащейся в дермисе, до температуры не превышающей температуру его денатурации 45-55°C. На второй фазе, при смещении максимума спектра излучения в красную область спектра, происходит селективный нагрев компонент волоса содержащих меланин: матрикса клеток и ствола волоса и находящихся рядом с ними папиллы и стим-клеток. Т.к. на 1 фазе их начальная температура становится на 9°-15°C выше обычной для

40 кожи, то для селективного нагрева и поражения на 2 фазе требуется на 30-40% меньшая энергия, чем при нагреве без 1 фазы. Для предохранения эпидермиса от поражения используется

45 контактное охлаждение, температура эпидермиса может измеряться и при достижении температуры кожи в течение 1 фазы заданного уровня, нагрев может быть остановлен, а энергия излучения на второй фазе устанавливается на безопасном уровне.

Отличительная особенность второй фазы состоит в том, что мощность лампы на этой фазе значительно превышает номинальную, но в силу наличия преднагрева лампы на первой фазе и малой длительности второй фазы это не приводит к
5 разрушению нити накала лампы.

Излучение лампы или нескольких ламп накаливания, как и в прототипе, с помощью рефлектора направляется на обрабатываемый участок кожи. В отличие от прототипа этот рефлектор в сочетании с волноводом построен так, что он
10 возвращает излучение, отраженное от биоткани, обратно в биоткань. Тем самым повышается эффективность использования мощности лампы. Дополнительно, эффективность устройства повышается за счет использования люминесцентного преобразователя энергии, ультрафиолетового, синего и зеленого
15 излучения в желто-красную область спектра.

Краткое описание фигур чертежей

Сущность изобретения поясняется фигурами, где на фиг.1 показана блок-схема устройства и сечение его наконечника. Фиг.2 показывает временные диаграммы мощности лампы, длины
20 волны максимума излучения, долей излучения лампы в инфракрасной и красной областях спектра, а также сопротивления лампы.

На фиг. 3 показано распределение температуры внутри кожи по окончании первой фазы - преднагрева, а
25 фиг. 4 иллюстрирует зависимости температуры базального слоя, стим-клеток и матрикса клеток волосяной фолликулы от времени на второй фазе.

Фиг. 5 показывает сечения наконечников упрощенного варианта устройства малой средней мощности и выполненных в виде
30 "щипцов". Фиг. 6 показывает сечение лампы устройства содержащей несколько "плоских" спиралей.

На фиг. 7 показано сечения наконечника содержащего четыре лампы.

Описанные ниже схемы и режимы работы предлагаемого
35 устройства не исчерпывают всех возможных вариантов реализации данного изобретения. Устройство может широко использоваться для термического воздействия на различные компоненты кожи с использованием лампы накаливания. Применение этого устройства не ограничивается фотоэпиляцией или фотомодификацией волос,
40 может использоваться для воздействия на крупные кровеносные сосуды, ножные вены с целью их лечения, на collagen дермиса с целью его регенерации, фотобиостимуляции и др.

Лучший вариант осуществления изобретения

Устройство состоит (фиг. 1) из наконечника 1, гибкого жгута
45 2 проводов и трубопроводов и блока питания и управления 3. Наконечник 1 состоит из галогенной лампы накаливания 4, которая помещена в трубку 5 из стекла или диэлектрического кристалла, рефлектора 6, выполненного из металла или оптического материала, на внутреннюю поверхность которого нанесено

высокоотражающее покрытие 7, фильтра-волновода 8, представляющего из себя сэндвич-структуру: люминесцентный преобразователь 9 - охлаждающая незамерзающая жидкость 10 - оптический теплоизолятор 11, призмы 12 из

5 высокотеплопроводного прозрачного диэлектрического материала и закрепленной в металлической оправе 13, которая через термоэлектрические элементы 14 (например, элементы Пельтье) подсоединена к охлаждаемым водой или воздухом терморadiatorам 15. Сэндвич-структура фильтра 8 образует с

10 диэлектрической призмой 12 оптический волновод. Оправа 13 с одной стороны имеет продолжение в виде металлической пластины 16, соединенной с термоэлектрическим элементом 14. Нижняя поверхность пластины 16 и призмы 12 находятся в контакте с обрабатываемой биотканью 17. К призме 12 приставлен

15 термосенсор 18, представляющий собой термopару, термистор или радиометр. Указанные детали смонтированы в теплоизолирующем корпусе 19. Наконечник 1 соединен с блоком питания и управления 3 с помощью жгута 2 электрических проводов 20 для питания лампы 4 и проводов 21 для питания термоэлектрических элементов

20 14. Жидкостные шланги 22 служат для подачи охлаждающей жидкости, которая должна циркулировать через отверстия 23 в рефлекторе 6 и терморadiatorе 15. Воздухопровод 24 служит для подачи и прохождения сжатого воздуха через канал 25 в корпус 19 и рефлектор 6, далее через отверстия 26 в трубке 5, рефлекторе 6,

25 корпусе 19 и в узлах крепления электродов 27. Провода 28 служат для подачи сигнала с термосенсора 18. Блок питания и управления 3 состоит из блока питания - 29, модулятора тока, напряжения или мощности - 30, компрессора 31, микропроцессора 32, и системы охлаждения с жидкостным насосом 33.

30 Устройство, на примере удаления волос, работает следующим образом: излучение 34 лампы 4 прямо или с помощью рефлектора 6 через блокирующий нежелательный спектр элемент 8 попадает на кожу 17 и воздействует на нее посредством поглощения водой. Это излучение воздействует также на цель -

35 например, на волосяную фолликулу 35 через поглощение света меланином или кровеносный сосуд через поглощение света элементами крови. Известно, что в следствии объемного рассеяния в коже значительная часть излучения рассеивается назад (S. R. Utz and et. Percutaneous blood laser biostimulation. First clinical results. Pros. SPIE, vol.1643, p. p. 228-239, 1992). Этот эффект максимален в красной области спектра, там где поглощение кожи минимально. Коэффициент отражения может достигать 80% процентов (Peters V.G. at all. Phys. Med. Biol.35, 1990, p.p. 1317-1334). Если, например, часть рефлектора 6, расположенная над лампой

40 накаливания 4, представляет собой часть сферы, а центр кривизны этой сферы расположен на ближайшей к лампе 4 грани 36 фильтра 8, то диффузно отраженное от кожи 17 излучение 34, пройдя волновод, образованный элементами 8 и 12, выходит через эту грань. Затем, попав на сферическую зеркальную поверхность 7

рефлектора 6, возвращается снова на указанную грань 36 и далее через волновод снова на кожу 17. В предлагаемом устройстве это излучение направляется назад на отражающее покрытие 7 рефлектора 6 и снова возвращается в кожу 17. Причем, тупой угол наклона боковой внутренней поверхности 7 рефлектора 6 обеспечивает попадание на сферическую часть даже лучей, которые выйдя из грани 36 попали на боковую поверхность.

Эффективность обратного отражения очень высока т.к. внутренняя поверхность 7 рефлектора 6 покрыта высокоотражающим материалом: Cu, Au или Ag или многослойным диэлектрическим покрытием. Коэффициент отражения превышает 90%. Кроме того площадь поверхности нити накала 37 лампы накаливания 4 очень мала, материал трубки 5 и рефлектора 6 обладает очень малым поглощением на длинах волн света, воздействующего на кожу 17. Поэтому, на каждое переотражение излучения в кожу 17 возвращается Rr^n часть падающей на нее энергии, где R - коэффициент отражения кожи, r - коэффициент отражения поверхности 7 рефлектора 6, n - число отражений. В результате многократных отражений освещенность внутри кожи увеличится в $\frac{1}{1-Rr^n}$. При R=0,8, r=0,90 и n=2 эффект усиления

освещенности достигает четырех раз. Следует отметить, что наилучший эффект усиления освещенности внутри кожи за счет рециркуляции фотонов обеспечивается при размере пятна более 10 мм.

Рассмотрим режим нагрева лампы с использованием блока питания 29 и модулятора 30. Для поражения волосяной фолликулы 35 наиболее благоприятная область спектра лампы 600-1100нм. В этой области меланин имеет достаточно высокое поглощение и в тоже время рассеяние составляет умеренную величину, так что свет может проникать в кожу на достаточную глубину. Галогенные лампы имеют пиковую температуру 3000°K - 3600°K. При 3000°K 5% излучения сосредоточено в области длин волн $\lambda < 600\text{нм}$, 34% в области $600\text{нм} < \lambda < 1100\text{нм}$, и 48% $1100\text{нм} < \lambda < 2500\text{нм}$. При 3500°K эти проценты перераспределяются так 10% $\lambda < 600\text{нм}$, 42% $600\text{нм} < \lambda < 1100\text{нм}$, 35% $1100\text{нм} < \lambda < 2500\text{нм}$. Таким образом, для максимальной эффективности преобразования электрической энергии в полезную световую энергию выгодно форсировать мощность и температуру галогенной лампы 4. Однако, при этом резко уменьшается срок службы лампы, если она работает в обычном непрерывном режиме. В предлагаемом изобретении используется электрический модулятор 30, с помощью которого на лампу 4 подается короткий мощный импульс тока или напряжения, вызывающего превышение рассеиваемой лампой мощности над номинальной. Исследования, проведенные авторами с лампой OSRAM тип ELC (Германия), имеющей номинальную мощность $P_n=250\text{Вт}$, показали, что температуре 2800°K соответствует мощность 150Вт, при токе 9А и напряжении 17В. Если ток повысить

- до 12,5А на промежуток времени 0,2 с, то в лампе будет рассеиваться мощность 360Вт, что в 1.45 раза больше номинальной (фиг. 2а). При этом температура достигает 3600°K, т.е. приближается к максимальной. В режиме, когда средняя температура нити порядка 2800°K, а на короткое время (0,2с) достигается максимальная температура 3600°K, лампа 4 может функционировать очень продолжительное время без деградации или разрушения. Временной диаграмме мощности лампы отвечает временная диаграмма светового излучения приведенная на фиг. 2б. Форма светового импульса может отличаться от формы электрического в силу тепловой инерции нити накала 37. Тепловая инерция зависит от диаметра нити накала 37. При практическом пределе диаметра нити 37 0,2мм, время тепловой инерции составляет 0,04с, а минимальная длительность светового импульса t_2 на полувысоте может достигать 0,1с. Для лампы мощностью 250Вт в таком импульсе может быть сосредоточено до 50Дж световой энергии при длительности 0,2с по полувысоте. Путем регулирования тока лампы 4 модулятором 30 также осуществляется перестройка спектра излучения лампы 4. На первой фазе длительностью t_1 ток лампы ниже номинального, температура нити 37 2800°K и максимум излучения лежит в ИК области спектра (1030нм). На второй фазе температура нити 37 достигает 3600°K и максимум излучения перестраивается в красную (800нм) область (фиг. 2 с). Соответственно изменяется доля излучения лежащая в области 1100-2500нм- $P_{ик}$ и 600÷1100нм - P_k (рис. 2д). Дополнительно, для автоматической защиты лампы 4 от разрушений в модуляторе 30 производится непрерывное измерение сопротивления лампы. При подаче импульса тока выше чем номинальный, сопротивление нити накала 37 увеличивается, и в момент t_m (фиг. 2д), когда сопротивление достигает критической величины, модулятор 30 автоматически ограничивает рассеиваемую мощность. С этой целью модулятор 30 содержит измеритель сопротивления 38 нити накала 37 лампы 4, связанный с регулятором тока, напряжения или мощности.
- 35 Способ обработки различных биотканей с помощью предлагаемого устройства определен исходя из степени восприимчивости той или иной биоткани к параметрам облучения. В частности для удаления волос способ использования устройства определен по свойствам кожи и волосяной луковицы(см. например, 40 A. Waldman et all Laser hair removal: theory and clinical experience Proc. of SPIE 1998 vol. 3245 p.p. 318-321).

Расчеты, проведенные по разработанной авторами математической модели, показали, что необходимы две фазы нагрева: длительный (преднагрев) и кратковременный (нагрев и 45 разрушение). Кроме того, для фотодеструкции волосяной фолликулы необходимо сначала охладить верхний слой кожи (эпидермис) затем, продолжая охлаждать начинать облучать кожу.

Действительно, в области спектра 1100÷2500нм кожа обладает сильным поглощением (поглощение воды) и слабым рассеянием. На отдельных участках спектра излучение может глубоко проникать в кожу. В диапазоне 600-1100нм преимущественным поглощением обладает меланин и гемоглобин крови. Таким образом, на первой фазе воздействия излучения на кожу осуществляется ее неселективный нагрев за счет поглощения излучения водой. На второй фазе осуществляется селективный нагрев структур кожи содержащих меланин (эпидермис, ствол волоса, матрикс клеток волосяной луковицы) и гемоглобин (кровеносные сосуды, вены). Роль первой фазы состоит в преднагреве поражаемой цели (волосяная луковица, кровеносный сосуд) с 30-36°C до 45-55°C, (что ниже температуры денатурации белка). Это производится с целью уменьшения уровня энергии необходимой для нагрева на второй фазе. На второй фазе коротким импульсом осуществляется нагрев поражаемой цели (волосяная луковица, сосуд) до температуры денатурации белка 65-75°C.

Обычно максимум освещенности находится на поверхности или в приповерхностном слое кожи. Это не позволяет осуществить равномерный нагрев глубинных слоев кожи. Наличие контактного охладителя 16 с отрицательной температурой, поддерживаемой холодильником в виде термоэлектрических элементов 14 или терморadiatorом 15 с циркулирующей водой, позволяет снизить температуру поверхности и приповерхностного слоя, а также сместить максимум температуры на первой фазе в глубь кожи. Комбинируя температуру охладителя и мощность лампы можно плавно управлять профилем температуры внутри кожи. Этот эффект можно использовать для селективного поражения коллагена с целью стимуляции его роста.

На Фиг. 3 показан типичный профиль температуры внутри кожи, рассчитанный для случая контактного охладителя из кристалла сапфира с температурой -10°C и лампы с номинальной мощностью 250Вт и температурой нити 3600°K через освещаемый участок кожи 1.5x1.5 см² и через 1 сек после начала воздействия (первая фаза). К моменту окончания этой фазы за счет использования контактного охладителя 16 температура базальной мембраны понижена до 17°C. Это позволяет защитить эпидермис от поражения на второй фазе.

На фиг. 4 показаны временные диаграммы температуры (вторая фаза) базальной мембраны (кривая 1), стим-клеток (кривая 2) и матрикса клеток волосяной фолликулы (кривая 3). Горизонтальная прямая (4) соответствует температуре денатурации белка. Максимальная температура лампы накаливания 3600°K, пиковая мощность в 1.45 раз больше номинальной, пиковая плотность мощности излучения в диапазоне спектра 600÷1100нм 81,6Вт/см², размер пятна 1.5x1.5 см², длительность второй фазы 0,2сек. Для достижения эффекта термического поражения волосяной луковицы 35 необходимо чтобы температура в области

папиллы, стим-клеток достигала температуры денатурации белка т.е. 65-75°C. Расчеты, проведенные на основе моделей кожи и волосяной луковицы с использованием данных описанных в литературе (M. H. Niemz "Laser-Tissue Interaction, Fundamentals and Application", Springer, 1995) показывают, что для конструкции прибора, описанного выше, оптимальный способ фотодеструкции волосяной фолликулы состоит в следующем: кожу предварительно охлаждают за счет контакта с металлической пластиной 16 и диэлектрической призмой 12, затем, сохраняя контакт и продолжая
5 охлаждать, нагревают дермис излучением в диапазоне 1100-2500 нм с максимумом 1300-1400 нм и плотностью 10-60 Вт/см² и с длительностью 0,1-100 сек. На второй фазе, непосредственно следующей за первой, проводится деструкция в волосяной фолликулы излучением длительности 0,05-10 сек в диапазоне 600-
10 1200 нм с максимумом в области 600-1000 нм и плотностью мощности 80-800 Вт/см².

Способ использования устройства для коагуляции кровеносных сосудов определен в основном из оптических свойств гемоглобина(см. например T.G.Pfefer et all Laser treatment of port
20 wine stains: three dimensional simulation using a biopsy-defined geometry in an optical-thermal model Proc. of SPIE 1998 vol. 3245 p.p. 322-333). Также как и в случае волосяной фолликулы необходимо предварительное охлаждение, затем, одновременно с охлаждением облучение в две фазы. Расчеты показывают, что на первой фазе
25 длительностью 0,1-100 сек облучение производится излучением в диапазоне 500-2500 нм с максимумом в области 700-1500 нм и плотностью мощности 1-50 Вт/см². На второй фазе для коагуляции сосудов или вен длительность воздействия должна быть 0,05-5 сек в диапазоне 400-1200 нм с максимумом в области 500-1100 нм и
30 плотностью мощности 10-500 Вт/см².

Описанное устройство может применяться также для селективного повреждения коллагена дермиса с целью стимуляции его роста и как следствие, улучшения косметических свойств кожи - снижение морщинистости, повышение эластичности или для
35 поражения подкожного жира. Как показали расчеты на основе нашей модели с использованием литературных данных (A. Welch, Optical-Thermal response of laser-irradiated tissue, Plenum Press, NY.,1996), оптимальным режимом для селективного поражения коллагена с помощью описанного устройства является следующий:
40 кожу охлаждают за счет контакта с металлической пластиной 16 и диэлектрической призмой 12 и облучают светом ламп накаливания в диапазоне 600-2500 нм с длительностью 0,1-1000 сек с плотностью мощности от 0.1 до 500 Вт/см². При этих режимах, за счет одновременного охлаждения поверхности и объемного
45 нагрева дермиса или подкожного жира излучением лампы накаливания, максимум температуры смещается в глубь кожи, и поражение слоя коллагена происходит внутри дермиса при сохранении эпидермиса. Глубина поражения определяется длительностью нагрева и охлаждения. Чем ниже мощность и

дольше охлаждение, тем глубже лежит область поражения. Охлаждение кожи при использовании описанного устройства может происходить при скольжении вдоль поверхности с сохранением теплового контакта. В этом случае новый необлученный участок
5 кожи сначала соприкасается с металлической пластиной 16 и предварительно охлаждается, а затем этот участок соприкасается с призмой 12 и охлаждается одновременно с облучением.

Изображенные на фиг. 5 упрощенные (в виде щипцов) варианты наконечника предлагаемого устройства отличаются тем,
10 что в них прозрачный диэлектрик 12 выполнен составным (разделенным на две половины вдоль плоскости симметрии 39) из материала, поглощающего вредное для обрабатываемой биоткани излучение лампы 4, т.е. в нем совмещены функции фильтра 8. При этом, каждая из половин закреплена на подвижных элементах, одни
15 части которых выполняет роль рефлектора 6 с функцией фокусировки излучения от лампы 4 на зафиксированном между половинами прозрачного диэлектрика 12, например путем элементарного зажима, фрагменте кожи 17. Половины рефлектора объединены с ручками 40, при смыкании которых вокруг оси 41
20 происходит зажим кожи 17. Устройство с таким наконечником более удобно использовать в домашних условиях.

Как видно из фиг. 5 (а, б, в) внутренняя поверхность рефлектора "щипцов" в сомкнутом состоянии имеет эллиптическую форму. Если в одном фокусе 42 эллипса помещены спираль нити
25 накала 37, то испускаемое из этой нити излучение 34 после отражения от эллиптической поверхности концентрируется во втором фокусе 43. Искажение хода лучей 34 из-за наличия диэлектрического элемента 12 будет минимальным, если испускаемые из одного фокуса 42 и отраженные от внутренней
30 поверхности эллипса лучи будут падать на этот элемент нормально. Для этого диэлектрический элемент 12 в сечении должен быть кругом. Возможна и многогранная форма (более технологична при изготовлении). Ориентация граней и их число выбирается в соответствии с условием концентрации максимальной доли
35 излучения во втором фокусе 43 эллипса.

На фиг. 5а представлены "щипцы" с формой внутренней поверхности 7 рефлектора 6 в виде эллипсоида вращения и спиралью нити накала 37, ориентированной вдоль большой оси 39
40 эллипсоида. В этом случае излучение нити накала 37 испускается преимущественно перпендикулярно этой оси 39 эллипсоида, и отражаясь от внутренней поверхности 7 рефлектора 6 попадает на диэлектрический элемент 12, который выполнен в форме шара 44 и закреплён с помощью фиксатора 45, со всех сторон и концентрируется в области второго фокуса 43 эллипсоида,
45 совпадающей с центром 46 шара 44.

На фиг. 5б и 5в представлены "щипцы" с формой внутренней поверхности 7 рефлектора 6 в виде эллиптического цилиндра и спиралью нити накала 37 ориентированной вдоль образующей цилиндра. В этом случае излучение нити накала испускается

преимущественно перпендикулярно образующей цилиндра и, отражаясь от внутренней поверхности 7 рефлектора 6 концентрируется во втором фокусе 43 эллипса. При этом, приведенная на фигурах форма диэлектрического элемента 12 (призма 47 или цилиндр 48) не изменяет направление излучения 34.

На фигуре 6 изображен вариант цилиндрической лампы накаливания 4 с четырьмя нитями накала 37 в одном баллоне, предназначенной для использования в наконечнике с охлаждением. Если нити накала в лампах изготовлены так, что ее геометрические размеры в плоскости, перпендикулярной освещаемой поверхности биоткани 17, намного меньше размеров нити в других направлениях, то излучение от нее испускается преимущественно параллельно этой плоскости. В результате снижаются потери на взаимное перерассеяние излучения одной нити накала на другие и эффективность устройства в целом возрастает. Расположение нескольких нитей накала в одной колбе позволяет в принципе избавиться от направляющих воздушный поток охлаждения трубок, уменьшить тепловые потери через газ, световые потери на колбах и направляющих воздух трубках, а также повысить технологичность изготовления ламп для данного устройства за счет упрощения конструкции токовводов.

На фиг. 7а изображено сечение в плоскости нитей накала изготовленного наконечника, предлагаемого в рамках данного изобретения, а на фиг. 7б - сечение в плоскости главной оптической оси сферической части рефлектора 6. Рефлектор 6 представляет сборную конструкцию из пластин. Четыре галогенные лампы вклеены в кронштейны 49, которые в свою очередь закреплены к пластине рефлектора винтами 50. В экспериментальном макете использовались четыре лампы типа ELS OSRAM. Излучение ламп 4 через стенки колбы и кварцевой трубки 5 прямо, или, отражаясь от покрытых серебром стенок рефлектора, изготовленного из сплава алюминия, попадали через спектральный фильтр, состоящий из рубина, тонкого слоя воды и кварцевой пластины на сапфировый диэлектрический элемент 12, а затем на поверхность кожи. В эксперименте поверхность кожи охлаждалась посредством системы охлаждения на основе элементов Пельтье марки ТВ-17-0,1.

Сечение волновода в контакте с кожей составляло 15х15 мм. В области спектра 650-1200 нм плотность мощности на поверхности кожи на 1 фазе, длящейся 0,5-1 сек составляет 20 Вт/см², а на второй длящейся 0,2 сек - 85 Вт/см². Как показывают расчеты, этой плотности достаточно для повреждения волосистой луковицы.

Вариант устройства, реализованного с одной галогенной лампой, представлен на фиг. 8. В этом устройстве лампа 4 своим наибольшим размером сориентирована горизонтально относительно поверхности кожи 17. Если форма накального тела несимметрична, то колба лампы ориентируется относительно поверхности кожи горизонтально таким образом, чтобы

- поверхность спирали 37 с наибольшей площадью была обращена к поверхности кожи. В данном случае волноводный эффект в направлении распространения излучения от лампы к коже обеспечивается главным образом элементом 51 в виде усеченной пирамиды 51 с высоким значением показателя преломления (не менее 1.76), а в направлении распространения отраженного от кожи излучения - зеркальной поверхностью 52. Пространство между поверхностью элемента 51 и поверхностью 52 образует собой кювету 53, соединенную с трубопроводом 54 заполненным талой водой с температурой $+1^{\circ}\text{C}$ из резервуара 55, которая поступает в сливной бак 56. Призма 12 выполнена из сапфира, закрепленного в металлической оправе 13, внутри которой предусмотрен проток жидкости с температурой $0^{\circ}\text{--}5^{\circ}\text{C}$, образующейся при таянии твердого многокомпонентного вещества, например, замороженного водно-спиртового раствора, помещенного в резервуар 57, который соединен с емкостью 58, где и собирается жидкость с температурой $0^{\circ}\text{--}5^{\circ}\text{C}$. Блок питания и управления 3 при данной реализации предлагаемого устройства может иметь в своем составе систему обратной связи, состоящую из исполнительного устройства и датчика (на чертеже не указан).
- Форма отражающей поверхности 7 рефлектора 6 и ее расположение в непосредственной близости к лампе 4 выбирается таким образом, чтобы длина оптического пути между излучающей поверхностью накаливаемого тела 37 лампы 4 и обращенной к ней поверхностью волновода 51 была минимальной и обеспечивала наибольшую светопередачу. Волновод 51 максимально эффективно, за счет явления полного внутреннего отражения, передает свет от поверхности 7 через жидкий фильтр и сапфировую пластину на поверхность кожи. Жидкий фильтр избирательно поглощает ИК компоненту излучения лампы, ослабляя интенсивность света в этой области спектра до оптимального уровня. Жидким фильтром является вода образующаяся при таянии льда в резервуаре 55 и под небольшим давлением попадающая в кювету 53, нагретая ИК излучением вода фильтра по трубопроводу попадает в сборную емкость для талой воды. Резервуар 55 и сборная емкость 56 для талой воды являются сменными элементами. Сапфировая пластина 12 охлаждается до температуры порядка $0^{\circ}\text{--}5^{\circ}\text{C}$ при протекании жидкости образующейся при таянии твердого многокомпонентного вещества (например замороженного водно-спиртового раствора) в резервуаре 57 по трубопроводам 59 расположенным внутри металлической оправы 13. Резервуар 56 и сборная емкость 58 для жидкости с температурой $0^{\circ}\text{--}5^{\circ}\text{C}$ также являются сменными элементами. Таяние льда и твердого многокомпонентного вещества начинается при помещении резервуаров 55 и 57 из холодильного устройства в устройство и происходит за счет притока тепла из окружающей среды при комнатной температуре. Необходимость использования жидкости с температурой $0^{\circ}\text{--}5^{\circ}\text{C}$ связана с необходимостью предохлаждения, например эпидермиса, до

температуры ниже 0°C при его соприкосновении с сапфировой пластиной 12 и металлической оправой 13 до, в процессе и после облучения. Таяние является фазовым переходом, что позволяет наиболее эффективно аккумулировать тепло от кожи и жидкого

5 фильтра.

Лампа электрически питается от блока питания, создающего электрические импульсы требуемого напряжения, тока и длительности. Блок питания может быть автономным, за счет помещения в его состав электролитического одно- или

10 многозарядного аккумулятора.

Необходимо отметить, что процедура обработки может быть болезненна. Для повышения комфортности и снижения травматичности в состав устройства введена система обратной связи. В простейшем варианте она состоит только из

15 исполнительного устройства, типа кнопочного переключателя или педали, прекращающего подачу электропитания по желанию пациента и может управляться пациентом. Возможны варианты когда в качестве датчика фиксирующего превышение порога боли выступает датчик размера зрачка глаза (при превышении порога

20 боли зрачок резко сокращается), скорости кровотока (при превышении порога боли скорость кровотока резко падает), значения температуры обрабатываемой поверхности (при превышении порога боли температура достигает определенного значения), по сигналам с которого исполнительное устройство

25 изменяет ток через протекающий через лампу или прекращающего подачу электропитания.

При использовании данного устройства фаза предохлаждения может занимать значительный промежуток времени, при этом излучение лампы отсутствует и появляется лишь

30 при достижении эпидермисом температуры близкой 0°--5°C, о чем свидетельствует поступающий с температурного датчика (термопары, терморезистора, радиометрического датчика и т.д.) сигнал.

В случае необходимости обработки биоткани с достаточно

35 большой площадью поверхности возможно одновременное использование нескольких подобных устройств, выходы которых образуют матрицу излучателей-охладителей находящихся в контакте с кожей .

Формула изобретения.

1. Устройство для терапевтической и косметологической фотообработки биоткани, содержащее блок питания (3) и помещенные в корпус источник электромагнитного излучения (34), выполненный в виде лампы накаливания (4), рефлектор (6) для концентрации этого излучения (34) на обрабатываемую биоткань (17), прозрачный диэлектрик (12) в виде волновода, соединенный с системой охлаждения и находящийся в контакте с обрабатываемой биотканью (17), а также спектральный фильтр, отличающееся тем, что лампа накаливания (4) соединена с блоком питания (3) через модулятор (30), который содержит измеритель сопротивления (38) нити накала (37) лампы (4) и регулятор мощности, а внутренняя поверхность рефлектора (6) представляет собой зеркальную поверхность (7), выполненную с дополнительной функцией возврата излучения (34), отраженного от обрабатываемой биоткани, обратно к биоткани (17).
2. Устройство для терапевтической и косметологической фотообработки биоткани по п. 1, отличающееся тем, что спектральный фильтр может быть выполнен в виде поглощающего фильтра (8).
3. Устройство для терапевтической и косметологической фотообработки биоткани по п. 1, отличающееся тем, что спектральный фильтр может быть выполнен в виде люминесцентного преобразователя (9).
4. Устройство для терапевтической и косметологической фотообработки биоткани по п. 1, отличающееся тем, что спектральный фильтр может быть выполнен в виде отражающего покрытия (7) рефлектора (6).
5. Устройство для терапевтической и косметологической фотообработки биоткани по п.1, отличающееся тем, что прозрачный диэлектрик (12) расположен в металлической оправе (13), закрепленной внутри корпуса (1), к которой с одной стороны вплотную присоединена, находящаяся в контакте с биотканью (17) металлическая пластина (16), соединенная с системой охлаждения (33).
6. Устройство для терапевтической и косметологической фотообработки биоткани по п. 1, отличающееся тем, что поглощающий излучение фильтр (8) выполнен в виде, образующей с диэлектриком оптический волновод, сэндвич структуры: люминесцентный преобразователь (9) - охлаждающая незамерзающая жидкость (10), оптический теплоизолятор (11).
7. Устройство для терапевтической и косметологической фотообработки биоткани по п.1, отличающееся тем, что область внутренней поверхности рефлектора (6), расположенная над лампой накаливания (4), имеет форму части эллипсоида или сферы с центром кривизны в центре ближайшей к лампе (4) грани (36) волновода, а область внутренней поверхности рефлектора (6), расположенная между лампой накаливания (4) и этой гранью наклонена к последней под тупым углом.

8. Устройство для терапевтической и косметологической фотообработки биоткани по п.7, отличающееся тем, что область внутренней поверхности рефлектора (6), расположенная между лампой накаливания (4) и ближайшей к ней гранью (36) волновода (8) представляет собой боковую поверхность усеченных конуса или правильной четырехугольной пирамиды, малым основанием которых является указанная грань, а двугранный угол между ней и боковой поверхностью или гранью лежит в пределах от 115° до 120° .
9. Устройство для терапевтической и косметологической фотообработки биоткани по п.1, отличающееся тем, что рефлектор (6) и прозрачный диэлектрик (12) выполнены из двух половин с общей осью вращения (39), на одной из половин рефлектора (6) с внутренней стороны расположена лампа накаливания (4), каждая из половин прозрачного диэлектрика (12) может быть выполнена с функцией спектрального фильтра и закреплена на соответствующей половине рефлектора (6) с учетом размещения биоткани (17) между половинами диэлектрика (12), в сомкнутом состоянии половин рефлектора (6).
10. Устройство для терапевтической и косметологической фотообработки биоткани по п. 9, отличающееся тем, что внутренняя поверхность рефлектора (6), в сомкнутом состоянии его половин, представляет собой эллипсоид вращения, в одном его фокусе (47) расположена спираль нити накала (37) лампы (4), ось которой ориентирована вдоль большой оси (39) эллипсоида, половины прозрачного диэлектрика (12) выполнены в виде шаровых сегментов (44), с основаниями параллельными большой оси эллипсоида и оси вращения половин рефлектора (6), шаровые сегменты закреплены на половинах рефлектора с учетом совпадения их общего центра со вторым фокусом (43) эллипсоида и расположенной между шаровыми сегментами биотканью (17).
11. Устройство для терапевтической и косметологической фотообработки биоткани по п. 9, отличающееся тем, что внутренняя поверхность рефлектора (6), в сомкнутом состоянии его половин, представляет собой поверхность эллиптического цилиндра, образующая которого параллельна оси вращения половин рефлектора (6), на уровне одного фокуса эллипса расположена спираль нити накала (37) лампы (4), ось которой ориентирована параллельно образующей эллиптического цилиндра, а половины прозрачного диэлектрика (12) выполнены в виде половин цилиндра (48), закрепленных на половинах рефлектора (6) с учетом совпадения оси этого цилиндра с расположенной, между его половинами биотканью (17) и второй фокальной осью (43) эллиптического цилиндра, причем направление образующей цилиндра (48) диэлектрика (12) совпадают с направлением ориентации оси спирали нити накала (37).

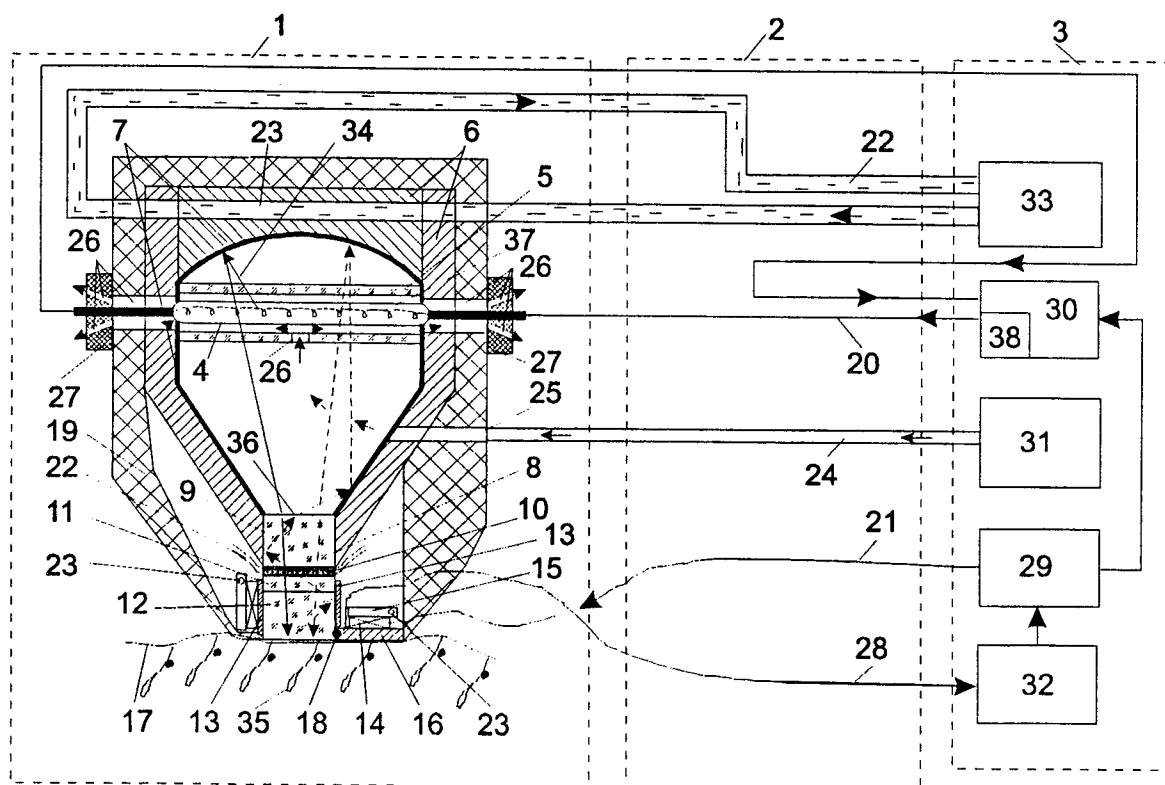
12. Устройство для терапевтической и косметологической фотообработки биоткани по п. 9, отличающееся тем, что внутренняя поверхность (7) рефлектора (6), в сомкнутом состоянии его половин, представляет собой поверхность эллиптического цилиндра, образующая которого параллельна оси вращения (39) половин рефлектора (6), на уровне одного фокуса (42) эллипса расположена спираль нити накала (37) лампы (4), ось которой ориентирована параллельно образующей цилиндра, а половины прозрачного диэлектрика (12) выполнены в виде прямых призм (47), с неправильными многоугольниками в основании, ориентированных боковыми ребрами параллельно оси вращения (39) половин рефлектора (6), закреплены призмы (47) так, что фокальная ось (39) эллиптического цилиндра совпадает с расположенной между призмами (47) биотканью (17).
13. Устройство для терапевтической и косметологической фотообработки биоткани по п.4, отличающееся тем, что зеркальная поверхность (7) рефлектора (6) выполнена из материала, селективно отражающего излучение (34) с длиной волны в диапазоне 600÷2500нм.
14. Устройство для терапевтической и косметологической фотообработки биоткани по п.1, отличающееся тем, что число ламп накаливания (4) или число нитей накала (37) в одной лампе (4) может быть больше одной, причем нити накала (37) могут быть плоскими.
15. Устройство для терапевтической и косметологической фотообработки биоткани по п. 9, отличающееся тем, что охлаждающая незамерзающая жидкость (10) дополнительно обладает свойствами поглощения излучения или переизлучения в другую область спектра и помещена в трубопровод (22), соединенный с нагнетающей помпой (33).
16. Устройство для терапевтической и косметологической фотообработки биоткани по п.1., отличающееся тем, что пространство внутри рефлектора (6) соединено с воздухопроводом подключенным к воздушному компрессору (31).
17. Устройство для терапевтической и косметологической фотообработки биоткани по п.1., отличающееся тем, что система охлаждения (33) прозрачного диэлектрика (12) и металлической пластины может содержать элементы Пельтье (14).
18. Устройство для терапевтической и косметологической фотообработки биоткани по п. 3, отличающееся тем, что люминесцентный преобразователь (9) и оптический теплоизолятор (11), входящие в сэндвич-структуру, выполнены соответственно из рубина или сапфира с титаном и оптического стекла, в том числе кварцевого.
19. Устройство для терапевтической и косметологической фотообработки биоткани по п.1., отличающееся тем, что оно

дополнительно снабжено системой водяного или воздушного охлаждения корпуса.

- 5 20. Устройство для терапевтической и косметологической фотообработки биоткани по п. 3, отличающееся тем, что в нем баллон лампы накаливания (4) и/или трубка (5) окружающая баллон (4) дополнительно выполнены с функцией люминесцентного преобразователя.
- 10 21. Устройство для терапевтической и косметологической фотообработки биоткани по п. 1, отличающееся тем, что нить накала (37) лампы (4) представляет собой плоский излучатель, плоскость которого параллельна плоскости обрабатываемой биоткани, а часть внутренней поверхности рефлектора (6) расположенная над лампой находится от ближайшей к лампе (4) грани (36) волновода на расстоянии не более $1.2d$ где d -
- 15 внешний диаметр колбы лампы.
- 20 22. Устройство для терапевтической и косметологической фотообработки биоткани по п. 1, отличающееся тем, что поглощающий излучение фильтр выполнен в виде сэндвич-структуры с функцией волновода для излучения от лампы (4) к биоткани (17) и обратно, и образованной в направлении перпендикулярном поверхности биоткани из четырехугольной усеченной пирамиды (51) изготовленной из прозрачного материала с показателем преломления не менее чем 1.76, большое основание которой, обращено к лампе (4), воды с
- 25 температурой от 1°C до 10°C и прозрачного диэлектрика кубической формы, находящегося в контакте с биотканью, а в направлении, параллельном поверхности биоткани - из той же четырехугольной усеченной пирамиды (51), воды с температурой от 1°C до 10°C и внутренней поверхностью (52) наконечника с
- 30 зеркальным покрытием.
- 35 23. Устройство для терапевтической и косметологической фотообработки биоткани по п. 1, отличающееся тем, что прозрачный диэлектрик (12) расположен в металлической оправе, снабженной системой охлаждения жидкостью с температурой от -1°C до -18°C .
- 40 24. Устройство для терапевтической и косметологической фотообработки биоткани по п. 1, отличающееся тем, что оно дополнительно снабжено системой обратной связи, в цепь которой входит датчик болевого порога пациента, нить накала (37) лампы (4) и блок питания (29).
- 45 25. Устройство для терапевтической и косметологической фотообработки биоткани по п. 1, отличающееся тем, что оно дополнительно снабжено прерывателем света управляемого по болевому порогу пациентом или датчиком боли в виде иридодиагностики илидиагностики кровотока.
26. Устройство для терапевтической и косметологической фотообработки биоткани по п. 1, отличающееся тем, что блок питания (29) снабжен аккумулятором.

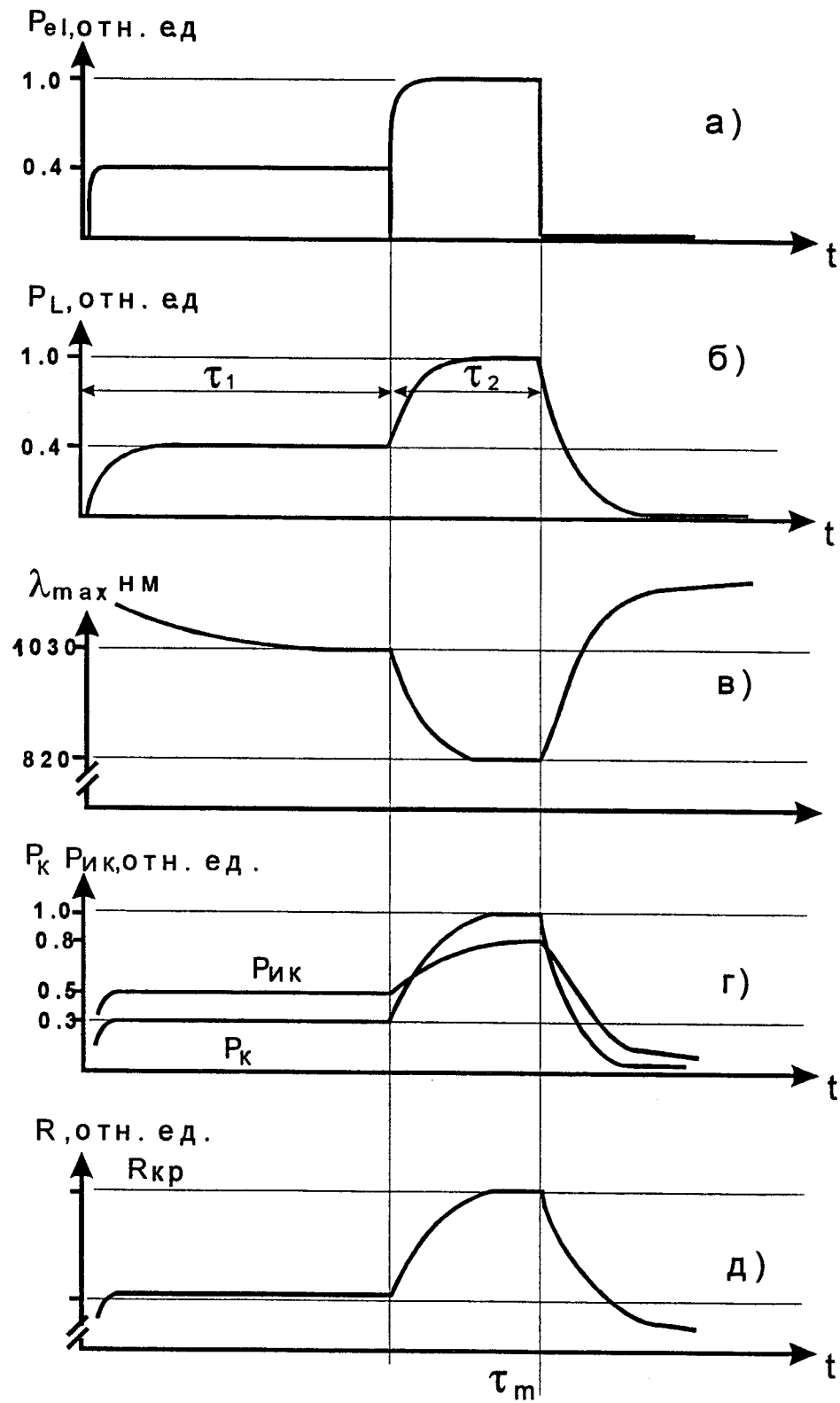
27. Способ терапевтической или косметологической обработки кожи, при котором кожу (17) предварительно охлаждают, затем, продолжая охлаждать, облучают светом (34), лампы накаливания (4) отличающийся тем, что для фотодеструкции волосяной луковицы (35), облучение производят двумя фазами, первая из которых предназначена для предварительного нагрева дермиса (17) до температуры не выше температуры денатурации и длится 0,1÷100сек в диапазоне 1100-2500 нм с максимумом в области 1300-1400 нм и плотностью мощности от 10 - 60 Вт/см², а вторая, непосредственно следующая за первой, предназначена для деструкции волосяной луковицы (35) и длится 0.05-10 сек в диапазоне 600-1200 нм с максимумом в области 600-1000 нм и плотностью мощности от 80 - 800 Вт/см².
28. Способ терапевтической или косметологической обработки кожи, при котором кожу (17) предварительно охлаждают, затем, продолжая охлаждать, облучают светом (34), лампы накаливания (4) отличающийся тем, что для фотодеструкции волосяной луковицы (35), облучение длится 0.05-10сек в диапазоне 600-1200 нм с максимумом в области 600-1000 нм и плотностью мощности от 80 - 800 Вт/см².
29. Способ терапевтической или косметологической обработки кожи, при котором кожу (17) предварительно охлаждают затем, продолжая охлаждать, облучают светом (34) лампы накаливания (4), отличающийся тем, что для фотокоагуляции кровеносных сосудов или вен облучение производят в две фазы, первая из которых предназначена для предварительного нагрева дермиса (17) до температуры не выше температуры денатурации и длится 0.1-100 сек в диапазоне 500-2500 нм с максимумом в области 700- 1500 нм и плотностью мощности от 1 до 50 Вт/см², а вторая, непосредственно следующая за первой, предназначена для коагуляции сосуда или вены и длится 0.05-1 сек в диапазоне 400-1200нм с максимумом в области 500-1100 нм, с плотностью мощности от 10 до 500 Вт/см².
30. Способ терапевтической или косметологической обработки кожи, при котором кожу (17) предварительно охлаждают, затем, продолжая охлаждать, облучают светом (34) лампы накаливания (4), отличающийся тем, что для селективного повреждения коллагена дермиса (17) с целью стимуляции его регенерации или селективного повреждения подкожного жира облучение производят светом в диапазоне 600-2500 нм с длительностью 0.1-1000 сек и плотностью мощности от 0.1 до 500 Вт/см².
31. Способ терапевтической или косметологической обработки кожи, при котором кожу (17) предварительно охлаждают, затем, продолжая охлаждать, облучают светом (34) лампы накаливания (4), отличающийся тем, что прозрачный диэлектрик (12) и металлическую пластину (16) устройства по п. 5 приводят в термический контакт с кожей (17), затем, устройство одновременно с облучением или в промежутках между облучениями перемещают вдоль поверхности кожи (17) так, что

новый необлученный участок кожи (17) сначала соприкасается с металлической пластиной (16), а затем с прозрачным волноводом (12).



Фиг.1.

2/10

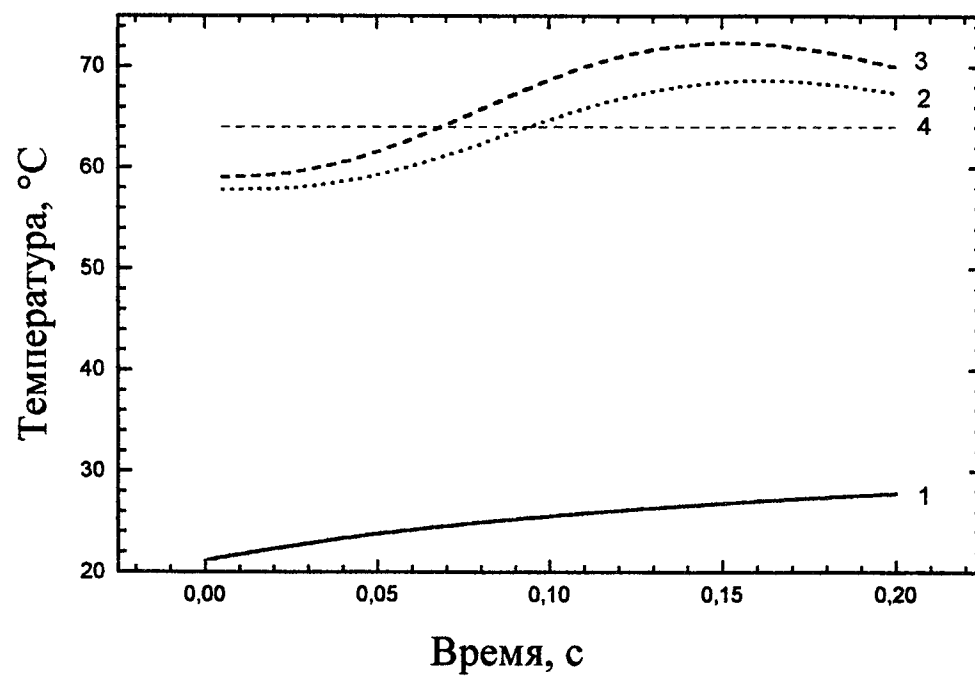


Фиг. 2

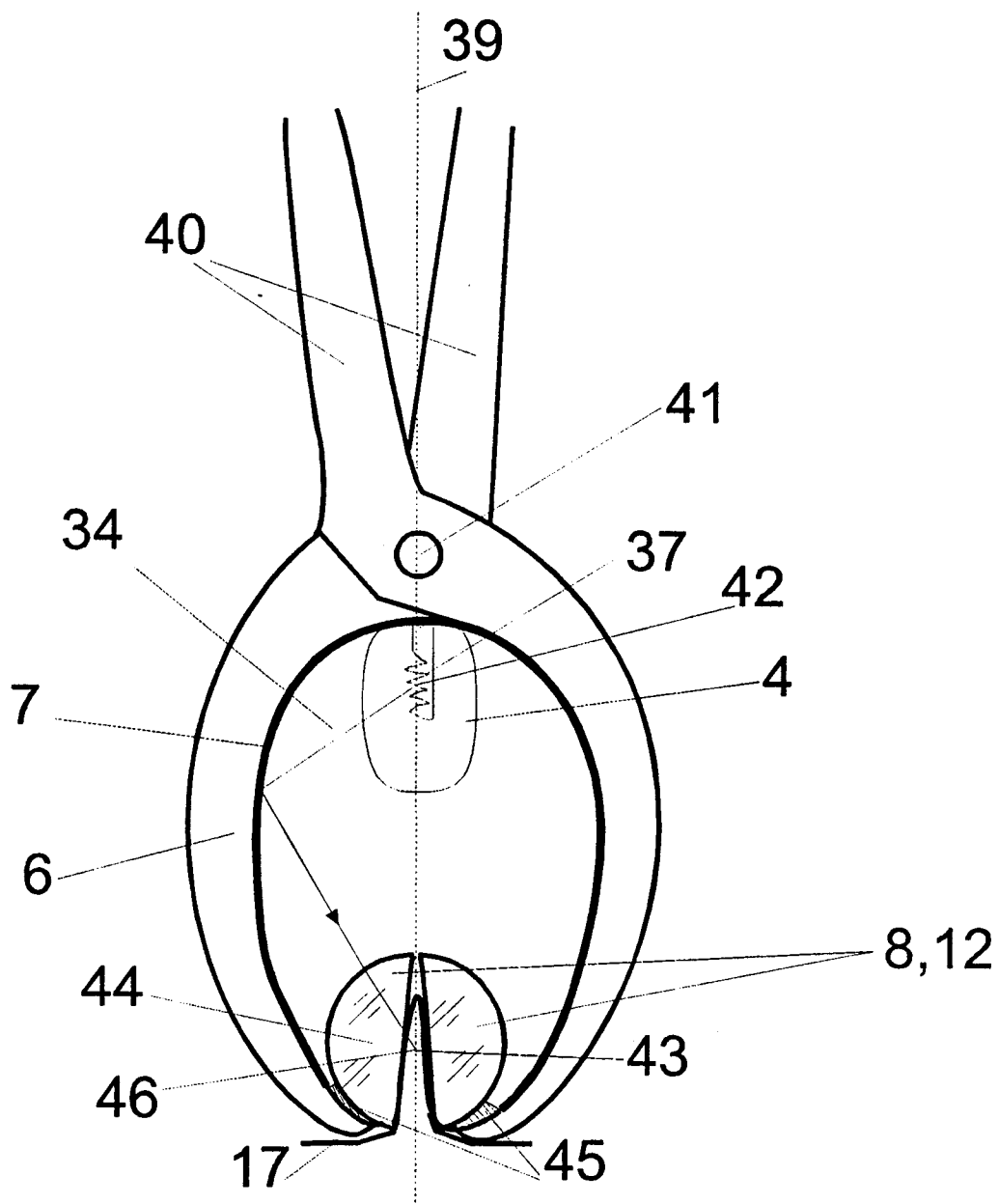
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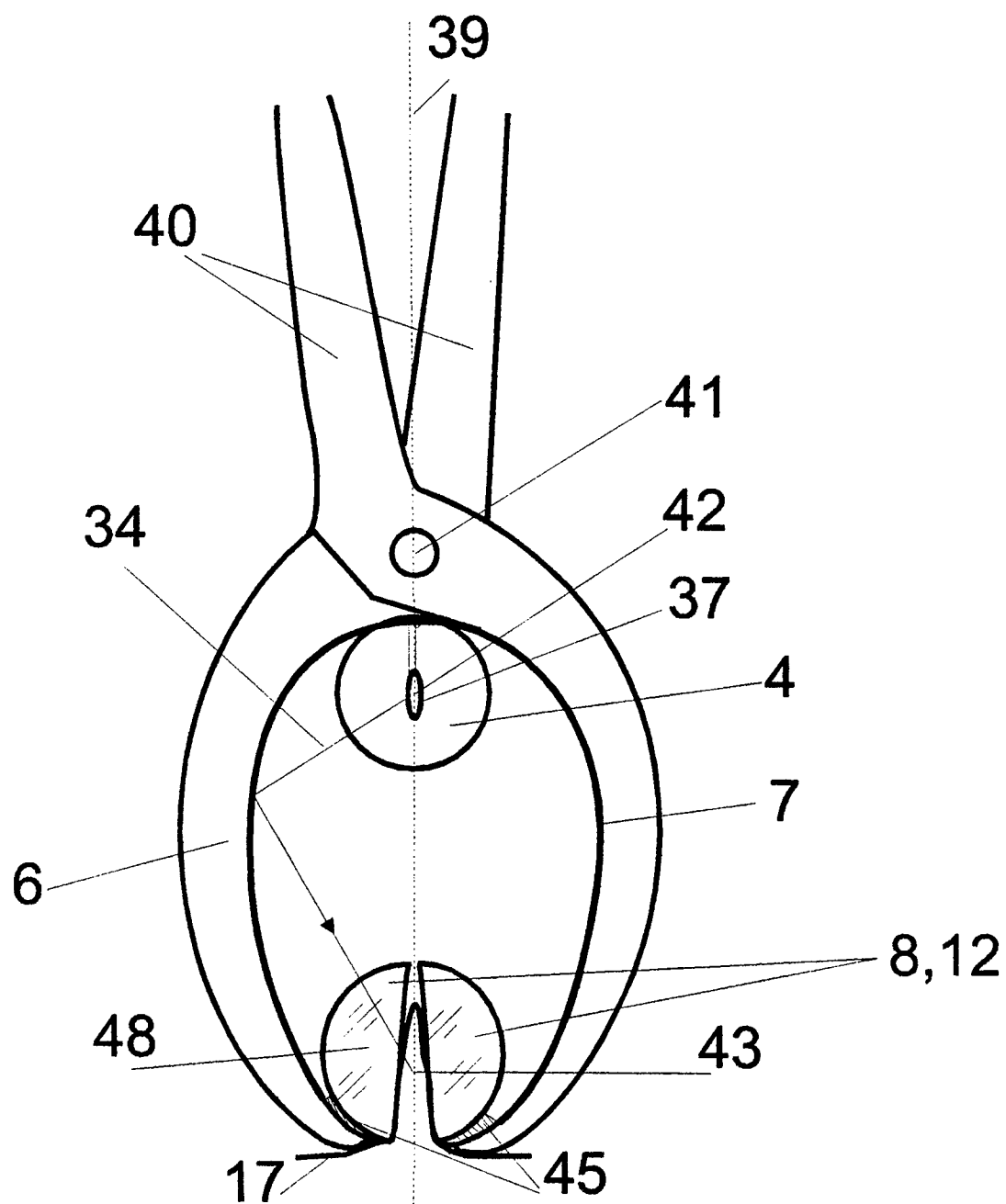
Фиг.3.



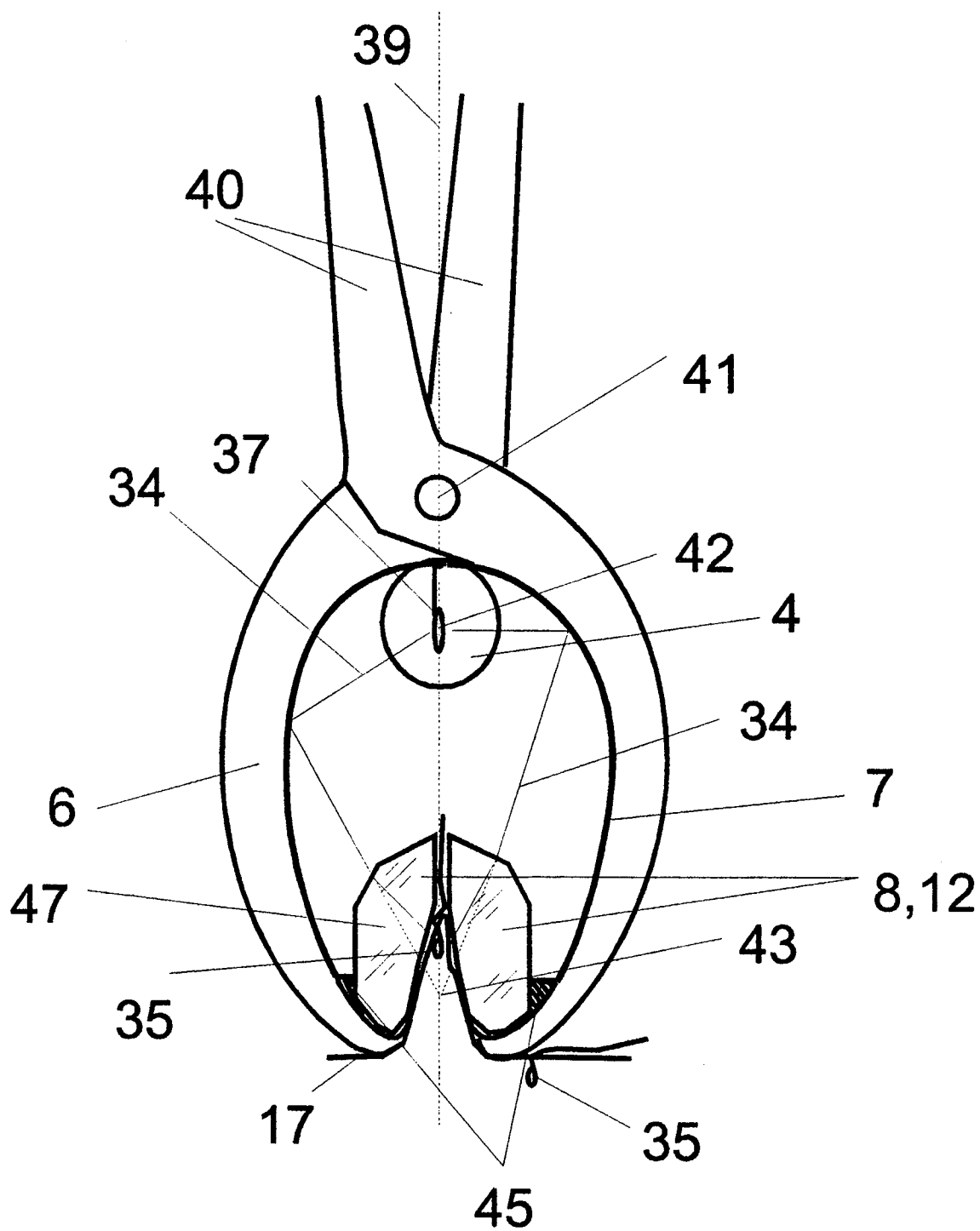
Фиг. 4.



Фиг. 5а.

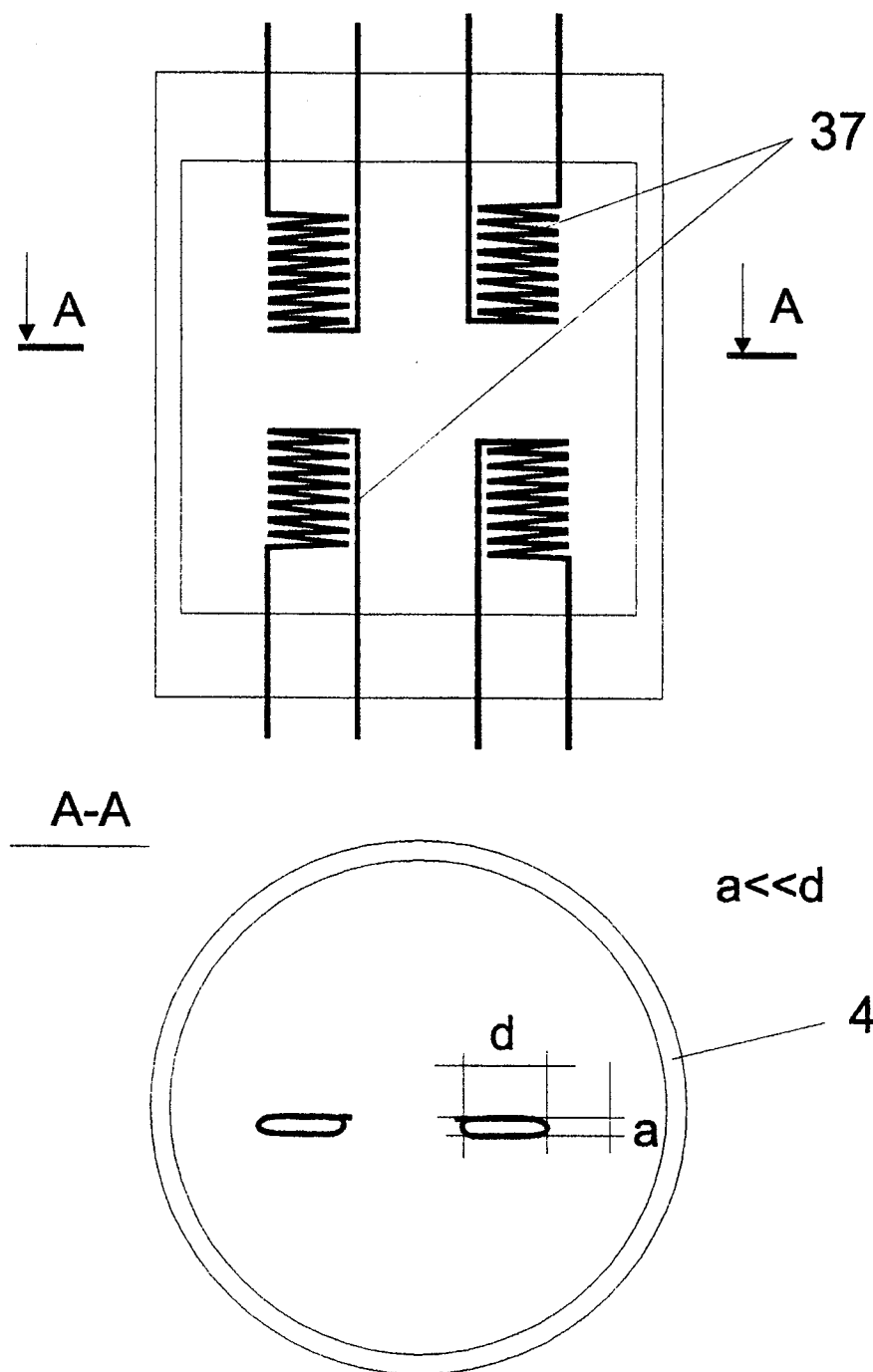


Фиг. 56.

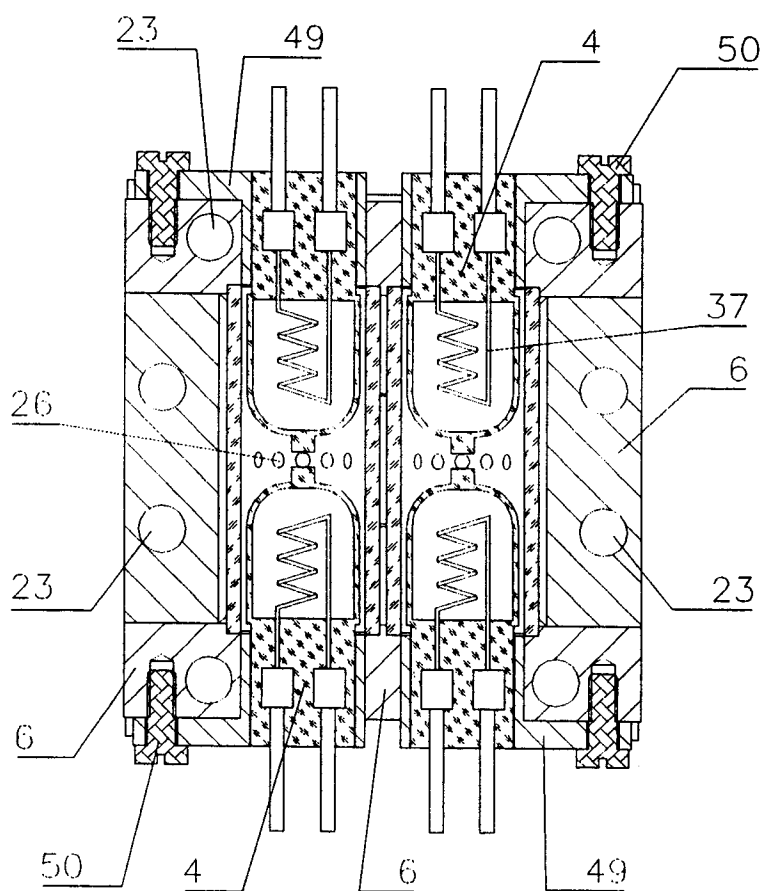


Фиг.5в.

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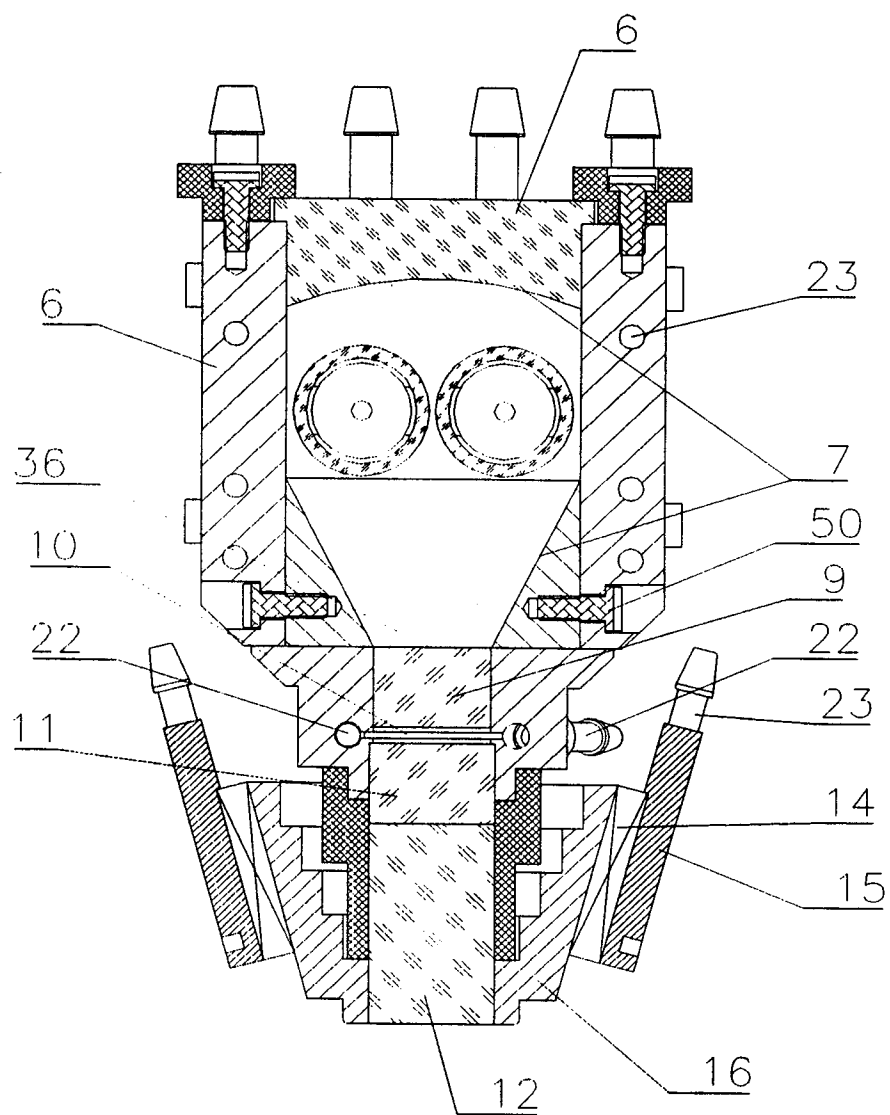


Фиг.6.

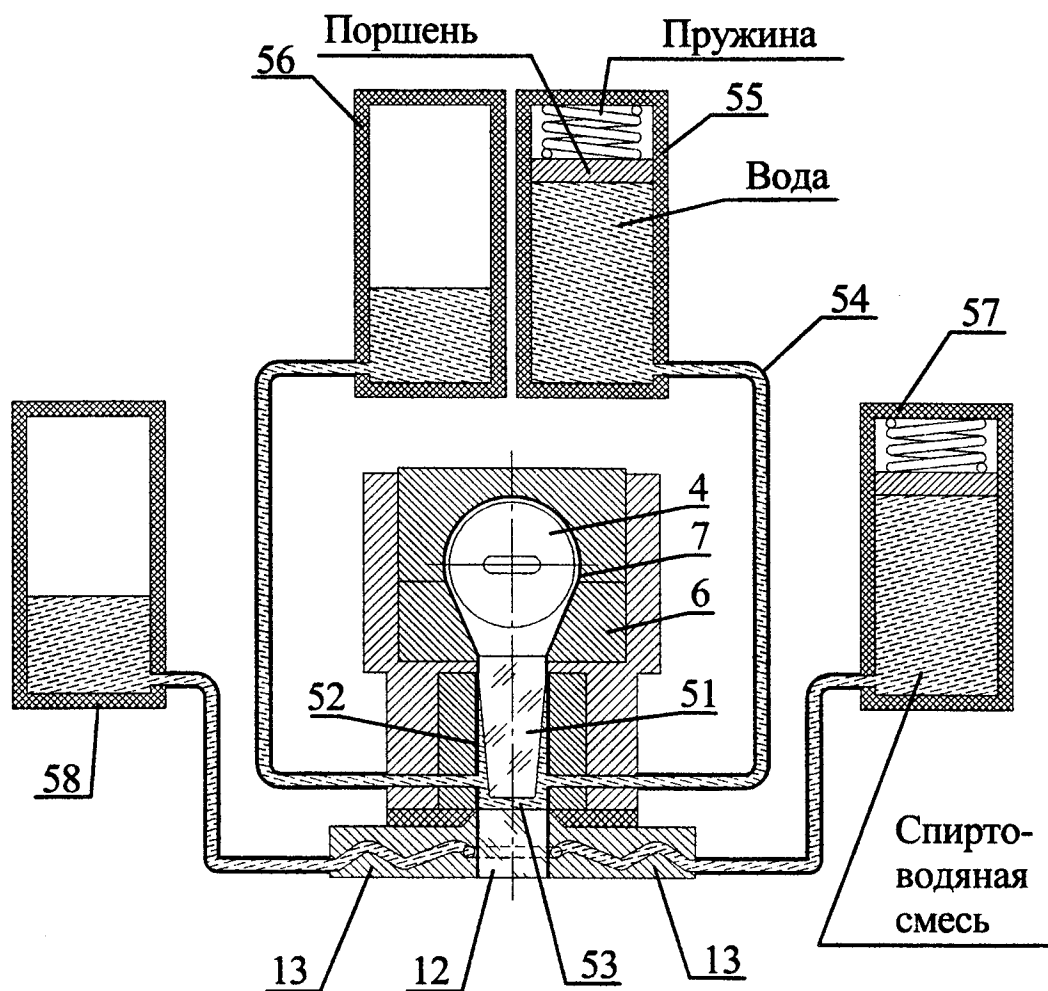


Фиг. 7а.

9/10



Фиг. 76.



Фиг 8.



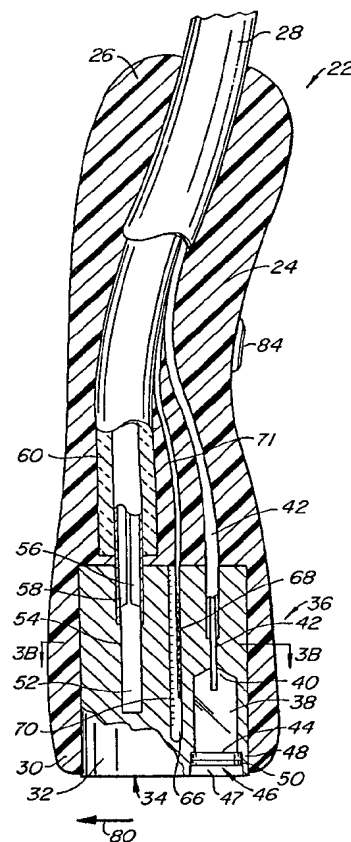
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(21) International Application Number: PCT/US00/06563 (22) International Filing Date: 13 March 2000 (13.03.00) (30) Priority Data: 09/270,118 15 March 1999 (15.03.99) US 09/357,745 20 July 1999 (20.07.99) US 09/393,830 10 September 1999 (10.09.99) US (71) Applicant: ALTUS MEDICAL, INC. [US/US]; 821 Cowan Road, Burlingame, CA 94010 (US). (72) Inventors: CONNORS, Kevin, P.; Suite B, 1181 Chess Drive, Foster City, CA 94404 (US). GOLLNICK, David, A.; Suite B, 1181 Chess Drive, Foster City, CA 94404 (US). SASNETT, Michael, W.; Suite B, 1181 Chess Drive, Foster City, CA 94404 (US). (74) Agents: HANN, James, F. et al.; Townsend and Townsend and Crew LLP, Two Embarcadero Center, 8th floor, San Francisco, CA 94111-3834 (US).		(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG). Published Without international search report and to be republished upon receipt of that report.

(54) Title: HAIR REMOVAL DEVICE AND METHOD

(57) Abstract

A hair removal device (22) includes a cooling surface (34) which is used to contact the skin (6) prior to exposure to hair tissue-damaging laser light (74) passing from a radiation source (36) through a recessed window (46). The window is laterally offset from the cooling surface and is spaced apart from the cooling surface in a direction away from the patient's skin to create a gap between the window and the skin. The window preferably includes both an inner window (46) and an outer, user-replaceable window (48). The laser-pulse duration is preferably selected according to the general diameter of the hair.



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HAIR REMOVAL DEVICE AND METHOD

BACKGROUND OF THE INVENTION

5 Use of light to denature very specific kinds of tissue has been called wavelength-selective photo-thermolysis. The use of lasers for this purpose has been well described in the literature. See, for example, R.G. Wheland, "Laser-assisted hair removal", Lasers in Dermatology, Vol. 15, pp. 469-477, and references cited. By choosing a laser with the right wavelength and energy per unit area (fluence), a particular
10 light-absorbing target substance (chromophore) in living tissue, such as melanin or hemoglobin, will absorb energy from the laser beam and become hot enough to destroy functionality in the tissue containing the chromophore. Tissue in the same area that does not have high concentration of the target chromophore will not be affected.

 Hair includes two basic parts, the shaft, which is the portion of the hair
15 above the epidermis, and the root, which is the portion below the surface of the epidermis. Various tissues surround the root of the hair. Hair color is primarily do to the presence of melanin in the hair. Melanin is created at the base of the hair follicle and is passed into the hair as it grows. The presence of melanin has made it possible to use lasers and other light sources for hair removal with melanin as the target chromophore. The hair follicle
20 and surrounding structure (referred to collectively as hair tissue) are selectively heated when the melanin in the hair tissue and in the hair root itself and is exposed to treatment radiation. The hair tissue is thermally damaged so that a result of the localized heating, many of the exposed hairs later atrophy and are sloughed from the epidermis.

 The early work in this field was centered around a wavelength with very
25 high melanin absorption, the pulsed ruby laser (694nm). Long pulse ruby lasers (as opposed to Q-switched ruby lasers) typically have a pulse duration in the 1 millisecond range. Although the wavelength is highly absorbed in melanin, the wavelength selection has significant limitations with darker skin types as the epidermis can blister from the superficial melanin heating.

30 Many different approaches to hair removal have been explored since the early ruby laser evaluation. A common trend is a continual shift towards longer wavelengths, which have less melanin absorption, as it allows treatment of patients with a

darker range of skin tones. Initially, alexandrite (755nm) was evaluated and later a diode approach (810nm). The alexandrite laser offers improved clinical capabilities over the ruby laser if one considers treatment of darker skin types. However, from engineering and system performance measures, the two systems are similar in terms of size, utility
5 requirement, treatment speed, and system cost. In contrast, the high pulse energy diode laser allows the system to be much smaller than previous systems with an ability to run off of standard power. One commercially-available system, sold by Coherent of Santa Clara as Lightsheer, weighs in the 45kg (100 pound) range and allows the physician to treat the darkest skin types with minimal risk of post operative blistering. Unfortunately,
10 the high pulse energy diode approach is very expensive as it requires up to 100 diode bars to achieve the peak powers needed for the desired clinical result. Another limitation with this approach is in the delivery device. The current Lightsheer system houses all diodes and associated hardware in a handpiece that is used in direct contact with the skin. This approach results in a heavy handpiece, weighing several pounds, that causes user fatigue
15 and an overall bulky design.

Dermatologists have used cooling devices in dermatologic applications prior to laser treatment. The purpose is to chill the skin with the understanding that exposure to treatment radiation will elevate the epidermal temperature. Chilling lowers the initial temperature so that the post treatment temperature at the epidermis will not
20 create a heat-induced blister. U.S. Patent 5,735,844 describes apparatus which uses a cooled lens, through which radiation passes, pressed against the patient's skin to cool the epidermis.

SUMMARY OF THE INVENTION

The present invention is directed to a hair removal device and method by
25 which hair tissue-damaging radiation passes from a radiation source through a recessed window to the patient's skin. The hair removal device also includes a skin-cooling element having a cooling surface which is used to contact the skin prior to exposure of that skin area to the radiation. The window is laterally offset from the cooling surface as well as spaced apart from the cooling surface in a direction away from the patient's skin
30 so to create a gap between the window and the patient's skin.

The presence of a gap between the window of the radiation source and the patient's skin offers several benefits. One problem associated with a contact cooling window in direct contact with the skin is debris build up. Dermatologic tissue

accumulates on the contact window as treatment pulses are delivered. The window must be periodically wiped in order to preserve the window from local, intense overheating that thermally and mechanically stresses the window and causes pitting. A recessed window does not exhibit this problem. Another advantage is that the window can be kept warm and above the local dewpoint temperature for both the inner and outer surfaces, so water and other condensables do not collect on it. Since the window is not in contact with the skin, it does not cause any re-heating of the pre-cooled skin.

In one embodiment of a hair removal device the radiation source includes an optical chamber having an exit aperture covered by the recessed window and an optical fiber entrance in which an optical fiber can be housed to permit tissue-damaging radiation to pass from the optical fiber into the optical chamber. The optical chamber may have reflective sidewalls to help equalize radiation fluence; a total internal reflecting optical element, such as a fused silica block, may be used to reduce losses. The optical chamber may also be heated to help prevent condensation from forming on the walls of the chamber or the window. A moisture wicking element may be used to wick condensation away from cooled surfaces adjacent the optical chamber to a heat sink or other heated element where the moisture evaporates. The window may include both an inner window and an outer, user-replaceable window; if the outer window becomes damaged through use, it can be easily replaced without affecting the integrity of the optical chamber. This is an advantage over fixed, single window designs that are rendered unusable if there is a surface imperfection due to, for example, localized pitting.

The hair removal device may be coupled to a laser which supplies laser light to the radiation source for passage through the recessed window. The laser may be controlled by user-operated laser power inputs including a laser-pulse duration input and one of a laser-pulse amplitude input and a laser-pulse fluence input. The laser-pulse duration input may be adjusted according to the diameter of the hair, which corresponds to the thermal relaxation time of the hair. Therefore, smaller diameter hairs will typically call for shorter laser-pulse duration inputs while larger diameter hairs will call for a longer laser-pulse duration inputs. Although larger diameter hairs will be selectively heated with short pulses, defined as a pulse duration shorter than the thermal relaxation time of hair, the peak power on the epidermis is unnecessarily higher than it needs to be. This can result in a heat-induced blister.

Another aspect of the invention relates to a method for preparing a hair-removal device for use including the steps of (1) determining the diameter typical of the hair to be removed, and (2) selecting a laser-pulse duration for a hair removal device according to this diameter of the hair so that smaller diameter hair results in a shorter laser-pulse duration than larger diameter hair. This aspect may be supplemented by the step of (3) applying laser energy through a window of a hair removal device of the selected laser-pulse duration to a patient's skin to cause thermal injury to hair tissue. This applies to both individual hairs and a plurality of hairs.

The methods may include selecting a chosen one of a laser-pulse amplitude and a laser-pulse fluence prior to the applying step. Further, the hair-removal method may also include positioning a cooling element of the hair removal device against a first target area and then moving, after a period of time, the cooling element from the first target area to a second target area so that the window overlies and is spaced apart from the first target area; laser energy is then applied to the first target area through the window with the window overlying and spaced apart from the first target area.

The pulse duration has been shown to have significant clinical implications. A short pulse, typically in the sub-5ms, range creates high peak powers because high fluence is required to deliver enough energy to achieve the proper clinical endpoint. High peak power tends to heat the epidermis. Longer pulses result in lower peak power.

Shorter wavelengths, such as 694nm, do not penetrate deeply into the patient's skin so, some believe, that it may be desirable, with such shorter wavelengths, to use a convex window pressing against the skin to shorten the path from the window to the hair tissue as is taught by U.S. Patent No. 5,735,844 patent. It has been found that by the use of longer wavelengths which are still absorbed by melanin, such as 800 to 1200nm, it is not necessary for the window of the radiation source to press against the patient's skin to effectively irradiate the hair tissue at a target area.

Another aspect of the invention is the recognition that it is not necessary to cool the skin the same time it is being irradiated. This is because once the skin has been cooled through contact with a cold surface, removal of the cold surface permits the skin to warm up but it does so much more slowly than it has cooled down because it is relying almost entirely on convection rather than conduction. Recognizing the fact that the skin remains sufficiently cool for a second or two after removal of the cooling surface permits

the window of the radiation source to be positioned spaced apart from the surface of the skin. This eliminates some problems created when the window of the radiation source directly contacts the skin during irradiation, such as window surface damage caused by intense heating from hair fragments that are heated by the laser beam.

5 A further aspect of the invention is the recognition that radiation in the longer wavelengths (about 800 to 1200nm) of the band of melanin-absorbing radiation, typically considered from about 600nm to 1200nm, can be used without the need for the use of chromophore contaminants as taught by U.S. Patent 5,425,728.

Other features and advantages of the invention will appear from the
10 following description in which the preferred embodiments have been set forth in detail in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a simplified cross-sectional view of a hair with its root within a
15 hair follicle;

Fig. 2 plots absorption coefficient versus wavelength for different substances including melanin;

Fig. 3 is a schematic representation of a hair removal assembly made according to the invention;

20 Fig. 3A is a simplified side view of the hair removal device of Fig. 3 with portions broken away to show internal detail;

Fig. 3B is a simplified cross-sectional view taken along line 3B-3B of Fig. 3A;

Fig. 4 is a bottom plan view of the hair removal device of Fig. 3A;

25 Fig. 4A is an overall view of the lower end of an alternative embodiment of the hair removal device of Fig. 3A;

Fig. 5 is a theoretical plot of fluence versus radial position for a diverging beam;

30 Fig. 5A shows an idealized plot of how to square off or equalize the fluence of the beam of Fig. 5;

Fig. 6 is a simplified view of the radiation source of Fig. 3 showing how radiation is reflected from the walls of the reflective chamber to help equalize radiation intensity and reduce hot spots;

Fig. 7 shows several idealized plots of temperature versus depth below the skin surface;

Figs. 8A, 8b, 8C and 8D are two isometric views, a top plan view and an end view of another alternative embodiment of the hair removal device of Fig. 3A with the ergonomically shaped body removed;

Fig. 9 is a simplified partial cross-sectional view of an alternative embodiment of the hair removal device of Fig. 3A in which the device is configured to permit the user to see the skin area being treated;

Fig. 10 is a simplified view of the bottom of a further alternative embodiment of the hair removal device of Fig. 3A showing leading and trailing cooling surfaces;

Fig. 11 is a partial cross-sectional side view of a hair removal device similar to that of Figs. 8A-8D but including a total internal reflecting optical element to help reduce laser radiation losses;

Fig. 12 is an embodiment similar to that of Fig. 11 but also including a moisture wicking element to help remove condensation which may be produced along the reflecting chamber adjacent to the cooled copper block; and

Fig. 13 is a simplified cross-sectional view taken along line 13-13 of Fig. 12.

DESCRIPTION OF THE SPECIFIC EMBODIMENTS

Fig. 1 illustrates, in simplified form, a hair 2 including a shaft 4 extending above skin surface 6 and a root 8 extending below the skin surface. The root 8 passes through epidermis 10 into dermis 12 with the base of the root being about 4mm below surface 6. Root 8 is housed within hair follicle 14, hair follicle 14 being surrounded by various tissues including connective tissue sheath 16 and blood vessels 18. The various tissues closely surrounding root 8 and connected with the growth of hair 2, including hair follicle 14 and connective tissue sheath 16, are collectively referred to as hair tissue 20 in this application.

Because melanin is also present in epidermis 10, with darker skin types having more melanin than lighter skin types, it is important that the wavelength be long enough so that absorption is low for the moderate concentrations in melanin in the epidermis to permit most of the light to pass through to the root 8 and hair tissue 20 where

melanin concentrations are relatively high compared to the epidermis. Therefore, it is preferred to use wavelengths in the 800 to 1200nm range; in particular, an Nd:YAG (neodimium-doped YAG) laser having a wavelength of 1.06 micron is preferred because it is a relatively efficient source and the technology is well developed and readily available.

Fig. 3 illustrates, schematically, a hair removal assembly 21 including a hand-held hair removal device 22, device 22 shown in more detail in the simplified views of Figs. 3A and 3B. Device 22 includes a hand-grippable body 24 having an upper or outer end 26 into which an umbilical cable 28 passes. Body 24 also has a lower or skin contacting end 30 housing a formed copper block 32, block 32 having various cavities to provide various features and functions as described below. Block 32 defines a cooling surface 34, see also Fig. 4, which is used to contact the patient's skin and cool the skin and prior to irradiation. Surface 34 is a low friction, high lubricity surface to help prevent bonding between the cooling surface and the skin.

Copper block 32 also houses a radiation source 36. Radiation source 36 includes a reflective chamber 38, in this embodiment having a square cross-sectional shape. Reflective chamber 38 has its walls covered with a highly reflective material, such as gold; the material is chosen for its reflective qualities for the particular wavelength radiation to be used. Other materials, such as dielectric layers combined with high-reflectivity metals, could also be used. Chamber 38 has an optical fiber entrance 40 to permit an optical fiber 42, or a bundle of optical fibers, to extend into chamber 38. The opposite end of chamber 38 has an exit aperture 44 covered by a recessed window 46. Recessed window 46 is spaced apart from cooling surface 34 by a distance or gap 47, such as about 1 to 3mm (.04 to .12in). Recessed window 46 includes an inner window 48, typically permanently or semi-permanently mounted to copper block 32 at exit aperture 44, and an outer window 50. Outer window 50 is removable secured in place by the use of an clip, not shown, or other suitable means. Windows 48, 50 are made of a suitable material, such as fused silica, although other materials, such as optical glasses, could also be used. By the use of inner and outer windows 48, 50, if outer window 50 is damaged, it can be easily replaced by the user. Accordingly, outer window 50 acts as a sacrificial window which if damaged, such as can occur through spalling as a result of bits of hair exploding when subjected to high power radiation, can be easily replaced.

Cooling surface 34 is cooled through the use of a coolant evaporator 52 housed within a blind bore 54 formed in copper block 32. The coolant, which may be of various commercially available types, commonly Freon® or other fluorinated hydrocarbons, is directed to evaporator 52 through a coolant liquid line 56 and is recycled back to a refrigerant compressor 62 (see Fig. 3) through a coolant vapor return line 58. Line 58 coaxially houses coolant liquid line 56, line 58 being housed within thermal insulation 60. Lines 56, 58 and insulation 60 pass through umbilical cable 28 to refrigerant compressor 62 associated with a control console 64. Alternatively, cooling surface 34 can be cooled by a thermoelectric, Peltier device instead of the coolant evaporator. This, currently preferred, embodiment of the cooling device is discussed below with reference to Figs. 8A-8D.

While it is desired to cool surface 34, such cooling can result in condensation on the surfaces of radiation source 36, in particular on the walls of chamber 38 and on recessed window 46. To help prevent this, a separation slot 66 is made between that portion copper block 32 used to cool surface 34 and that portion of the block used for radiation source 36. An electrical, typically resistive, heating element 68 is positioned along one wall of slot 66, the right wall as shown in Figs. 3A and 3B, while the other, left wall is covered with thermal insulation 70. Heating element 68 is connected to console 64 through a conductor 71 extending along umbilical cable 28. In lieu of resistive heating element 68, the hot side of a thermoelectric type of heating element, such as discussed below with reference to Figs. 8A-8D, could be used.

Laser hair removal treatments are designed to be effective and yet safe. That is, the treatment should cause thermal damage to hair tissue 20 but not substantial damage to surrounding tissue, such as blistering to the skin. To do so the energy per unit area (fluence) of the laser beam 74 at skin surface 6 must be controlled. Part of this control requires that the distance between skin surface 6 and the end of optical fiber 42 be controlled because beam 74 expands as it passes through reflective chamber 38. The distribution of energy across the laser beam at the skin surface should be substantially constant so that no hot spots, which could cause local damage to the epidermis, are created. Also, the individual exposure sites must fit tightly together, commonly called a tiled effect, so that there is little or no overlapping of the exposure sites and, at the same time, little or no area is left unexposed. The simplest shape that meets this tiling requirement is a rectangle. Other shapes can create a tiled pattern but they have other

drawbacks. Reflective chamber 38 and window 46 both have square cross-sectional shapes for efficient and effective treatment.

Fig. 5 illustrates a graph of fluence versus radial position for a diverging beam, such as from optical fiber 42. What is desired is to square off the graph to equalize the fluence over the beam spot. This is suggested in Fig. 5A in which those portions of the beam at the edges are reflected or folded over back into the main portion of the beam to create a generally square wave graph of fluence versus radial position. Fig. 6 illustrates how this is accomplished with the present invention. The walls 72 of chamber 38 are made to be highly reflective of the particular wavelength of radiation. In the preferred embodiment the wavelength is 1.06 micron and surface 72 is provided with a highly reflective gold surface. As suggested in Figs. 5A and 6, the diverging laser beam 74 not only passes directly through window 46 but the edge portions of the beam are reflected off the walls 72 back into the main portion of the beam to create a generally equalized fluence level. Other optical arrangements can be used to help equalize the fluence applied to skin surface 6. For example, various devices called optical integrators or beam homogenizers are well known in the art of laser material processing. The simplicity of the present device is possible because the exit aperture, by virtue of being close to the cooling surface 34, is located close to the target surface.

In another embodiment, shown in Fig. 9, reflective chamber 38, exit aperture 44 and protective window 46A are spaced much further from the skin surface to, for example, give the practitioner a better view of the treatment area 73 through a view port 75. View port 75 may be an open region, as illustrated, or it could include, for example, transparent and/or reflective members to permit direct or indirect viewing of area 73. In this case, a lens system 77 is used between exit aperture 44 and window 46A to make an image of the exit aperture on the skin surface at treatment area 73. With this approach, the size of the exit aperture need not be the same size as the treatment area 73 on the skin surface. The size of treatment area 73 could be made variable by proper selection of the focal length of lens system 77 and the distance between exit aperture 44 and the lens system. This would be useful when it is desired to use the device for other treatments, such as the treatment of varicose veins.

One way to control unwanted thermal damage to the skin is to cool the epidermis. Fig. 7 illustrates several idealized plots of tissue temperature versus depth below the skin surface. Plot A shows the normal variation of temperature versus depth

with the temperature rapidly approaching the normal core temperature of 37°C. Plot B illustrates the temperature at a range of tissue depth following a laser pulse when there has been no prior cooling of the skin. Assuming the energy is high enough to cause thermal damage at a depth of about 2 to 4mm, the typical range of depths need to cause damage to hair tissue 20, the skin surface temperature is hot enough to cause blistering and burning. The blistering and burning range is indicated by region 76, that is above about 68°C, while the temperature needed to cause hair tissue damage is indicated by region 78, that is above about 48°C. Plot C illustrates the result of cooling the skin surface after adequate pre-cooling. Adequate pre-cooling has commonly been found to be created when an copper heat sink, pre-cooled to about 0°C, is applied to the skin surface for about 1 to 2 seconds. Plot D plots temperature versus skin depth immediately after exposing the skin surface, pre-cooled as in the Plot C, to a laser-pulse similar to that which created Plot B. As can be seen, pre-cooling the skin surface results in prevention of burning or blistering the skin while permitting the target tissue, that is hair tissue 20, to be raised to a sufficiently high temperature to cause thermal damage to the tissue. Note that the plots in Fig. 7 are not taken from actual test data but are idealized plots provided to aid understanding the advantages of pre-cooling of the skin.

Several patents discuss surface cooling to prevent tissue damage. See, for example, U.S. Patents 5,057,104; 5,282,789 and 5, 735,844. Coherent of Santa Clara, California sells a diode laser system for dermatological use as the LightSheer. This product provides a hand piece with a cold window through which the laser exposure occurs. To use the device the window is first pressed against the treatment side for a period of time and then the laser beam is fired through the window. One of the problems with this simultaneous cooling technique when applied to laser hair removal is that it takes two to three seconds with the skin in contact with the cooled window to properly cool the skin surface to about 10 to 15°C. Thus, the practitioner must wait for about one to three seconds at each treatment site before firing the laser-pulse.

The present invention eliminates any need to wait prior to firing the laser-pulse by separating the cooling surface and the laser discharge window. As seen in Fig. 4, cooling surface 34 lies adjacent to window 46 in the direction of movement indicated by arrow 80. The width of surface 34 and window 46 are substantially the same while the length of 34 is about twice the length of window 46, that is with the length considered to be in the direction of arrow 80. Assuming a cooling time of two seconds is desired, the

forward end 82 of cooling surface 34 is placed over the first target area on skin surface 6. After about one second in that position, device 22 is moved in the direction of arrow 80 the length of recessed window 46; in the preferred embodiment this is about one centimeter. At this time the first target area shifts to a position covered by cooling surface 34 but adjacent to window 46. After a second one-second interval, device 22 is again moved the length of recessed window 46; at this time the first target area, which has been cooled for a total of about two seconds, is aligned with recessed window 46. The practitioner then presses a fire button 84 on body 24 of device 22 causing a laser-pulse to be directed at skin surface 6. The practitioner then continues moving device 22 and pressing fire button 84 at one-second intervals to provide the desired laser treatment of the skin surface.

The desired two-second cooling of skin surface 6 could also be done with cooling surface 34 about the same size as window 46. To do so would require that device 22 be moved only every two seconds, or some other length of time needed to cool the skin surface 4. By making cooling surface 34 with a length greater than the length of window 46, the amount of time between laser-pulses need not be controlled by how long it takes to cool the skin surface. Rather, the device can be designed so that the time between laser-pulses is chosen to be at a comfortable pace for the operator while not unduly extending the time the entire procedure takes. For example, if it is believed that the proper interval between pulses is three-quarters of a second but the skin area needs to be cooled for three seconds, the length of cooling surface 34 could be made to be about four times the length of window 46; using these parameters, moving device 22 by the length of window 46 between each pulse permits the skin surface to be cooled for the desired three seconds while the practitioner can operate the fire button at the desired three-quarter second between pulses. Therefore, the length of the cooling surface (Y) is equal to the length of the window (X) multiplied by the time desired to cool the target site (C), the result divided by the desired interval between laser pulses (Z); that is , $Y=(X \times C)/Z$. Adjustments to the thermal capacity, thermal conductivity and temperature of block 30 and cooling surface 32 can also be made to vary the required time needed to cool skin surface 6.

Fig. 4A illustrates an alternative embodiment of the invention in which window 46A is rectangular having a width about three times its length. In this case cooling surface 34A would have a width about equal to the width window 46A.

However, the length of cooling surface 34A is, like in the embodiment of Fig 4, about twice the length of window 46A based on the premise that the interval between actuation of fire button 84 will be equal to one-half the length of time it is desired to apply equal surface 34A to the skin surface to properly cool the skin surface.

5 The pre-cooling of the skin surface followed by the irradiation is based on the premise that the skin can be cooled relatively quickly compared with the time it takes to warm back to its normal temperature. For example, in one experimental trial using a cooling surface 34 maintained at about 0°C and applying the cooling surface to skin surface 6 for one second lowered the skin surface temperature about 12°C; application for
10 two seconds lowered the skin temperature by about 18°C; application for three seconds lowered the skin temperature by about 20°C. Therefore, two seconds of cooling time appears to be adequate with this particular cooling surface; three seconds of cooling time is better but only marginally so. While one second of cooling time does produce a significant drop in skin temperature, it may not be adequate depending upon various
15 factors, primarily the amount of pigment in the patient's skin, the patient's hair color and other such factors. Accordingly, it is believed cooling times from about one to two seconds, and generally more preferably about two seconds, are expected to produce good results at a reasonable pace with the disclosed embodiment.

 In another mode of operation which could be used by experienced
20 practitioners, the laser system would be set to emit pulses continuously at a constant repetition rate of, for example, 1 Hz. The practitioner would hold the handpiece in continuous contact with the patient's skin and move it at a constant velocity equal to the product of exposure-area length time repetition rate. This will maximize the rate at which the treatment proceeds while still providing adequate skin cooling and complete coverage.

25 Figs. 8A-8D illustrate another alternative embodiment hair removal device 22 but with the ergonomically shaped body shown in Fig. 3 removed. Device 22A is similar to device 22 but instead of using coolant evaporator 52, device 22 uses a thermoelectric device 88, typically a Peltier device. Thermoelectric device 88 has a warm part 85 and a cold part 86 created by the passage of electricity through the thermoelectric device. To remove the heat created at warm part 85, thermoelectric device 88 includes a
30 water cooled copper heat sink 90 having inlet and outlet lines 92, 94. The cold part 86 of device 88 is thermally coupled to copper block 32A by a bar extension 93 of block 32A so to cool cooling surface 34A, block 32A being gold-plated.

Fig. 10 illustrates another embodiment of the invention in which recessed window 46 is centered between two cooling surfaces 34. This provides two advantages: (1) the practitioner can move device 22 in either direction, back and forth, without having to rotate the handpiece, (2) the trailing cooling surface will reduce both pain and trauma to the skin following the laser exposure. This will be particularly important for the treatment of patients with darker skin types.

Fig. 11 illustrates a further embodiment of the invention similar to the embodiment of Figs. 8A-8D and also with the ergonomically shaped body shown in Fig. 3 removed. Reflective chamber 38B of hair removal device 22B includes a total internal reflecting optical element 100 having an entry surface 102 which accepts laser beam 74, an exit surface 104 facing recessed window 46, and a total internal reflecting sidewall surface 106. By partially filling gold-plated chamber 38B with optical element 100, typically a rectangular fused silica block, the same goal of uniform fluence can be achieved with much reduced optical absorption loss. The gold plating on wall 72B still remains important to maintain reflectivity as high as practical for light scattered back from the treated skin. Entry and exit surfaces 102, 104, windows 48, 50 and optical fiber 42 are preferably coated with thin dielectric layers to reduce reflection losses.

Fig. 12 illustrates a slightly modified version of the hair removal device 22B of Fig. 11. Hair removal device 22C has a moisture wicking element 108, typically made of a refractory material such as glass or ceramic fibers that will not be affected by the laser beam if element 108 happens to be struck directly or indirectly by the laser beam. Element 108 is wrapped around the distal end 110 of reflective chamber 38A adjacent to copper block 32A. Element 108 continues along copper block 32A and then up along the side of water cooled heat sink 90C. Water cooled heat sink 90C is warm enough so that condensation which may collect at or near distal end 110 of reflective chamber 38A can be wicked away and evaporated by the heat generated by thermoelectric device 88. Doing so will help keep optically sensitive areas dry and free of conservation. In addition, the evaporation of water will help cool heat sink 90C. It may be necessary or desirable to provide vents or other structure to help remove warm, moist air produced by evaporating moisture from element 108 at heat sink 90C.

One embodiment of the laser system can operate at average power output levels of up to 120 watts delivered to tissue. Under these conditions there is enough absorption of laser power in reflective chamber 38A that it is important to thermally

connect it to a heat sink. One choice would be to connect chamber 38A to the cold part 86 of the thermo-electric cooling assembly. The problem with this configuration is that when device 22C is not delivering laser energy at a high rate, reflective chamber 38A would become cold enough to condense water vapor out of the air and could collect liquid water on sensitive optical surfaces. A better choice of heat sinking chamber 38A is to thermally connect it to water-cooled heat sink 90C. The cooling water can be supplied from the same circulation system used to cool the laser itself; this water is typically cooled by a water-to-air heat exchanger (not shown). When so cooled the cooling water can never be colder than room temperature and is usually at least several degrees to a few tens of degrees C warmer than room temperature. This helps to ensure that the reflective chamber is always above the dew point and therefore incapable of condensing water out of the air.

Thermal coupling of heat sink 90C with chamber 38A is provided by an extension 112 of heat sink 90. Extension 112 passes through a cut-out in a circuit board 116 and contacts a proximal end 118 of reflective chamber 38A. See Figs. 12 and 13. A pair of set screws 120 are used to secure proximal end 118 to extension 112 for stability and to ensure good thermal contact. Heat sink 90 is typically made of copper and chamber 38A is typically made of aluminum so that heat sink 90 keeps chamber 38A warm enough to help prevent condensation on chamber 38A.

Another aspect of the invention relates to the control of the laser-pulse according to the diameter of shaft 4 of hair 2. Part of this selection is based on the belief that laser-pulse duration should be selected to match the thermal relaxation time of the targeted hair. For small diameter hair the pulse should be shorter while for larger diameter hair the pulse should be longer. This belief is used in conjunction with the belief that high peak powers should be avoided. Thus, it is preferred to use longer pulse durations with lower peak powers and to selectively adjust the duration according to the shaft diameter to minimize or eliminate damage to epidermis 10 while not sacrificing heat transfer to hair tissue 20. With this in mind, it is believed that a wavelength in the range of about 800 to 1200nm would be quite suitable for use with the present invention. For the preferred embodiment a wavelength of 1.06 micron has been chosen. The choice of a 1.06 micron laser is beneficial for many reasons. It permits treating of patient having darker pigmented skin than the shorter wavelength lasers commonly used. The 1.06 micron laser is relatively efficient, requires no special cooling and has the ability to create

high pulse energy (such as about 4000 watts in one preferred embodiment) in low duty cycle pulses without large power-consuming support systems. Further the 1.06 micron laser can use flash lamp excitation which can be engineered at a fraction of the cost of high peak power diode lasers.

5 Console 64 is provided with control panel 95 (see Fig. 3) having a number of inputs 96 to provide the desired user control. Inputs 96 include a laser-pulse duration input, which is chosen according to the hair shaft diameter. The laser-pulse duration pulse input could be selected in terms of actual or relative time duration or in terms of actual or relative hair shaft diameter thickness. In addition to the laser pulse duration
10 (hair shaft diameter) input, control panel 96 also includes one or both of a laser-pulse amplitude input or a laser-pulse fluence input. Other inputs to permit other variables to be controlled can also be provided. Console 64 may also include a display 98 to provide the user with information, such as the temperature of cooling surface 34, optimal laser pulse actuation rate, laser-pulse duration selected, etc. In one preferred embodiment
15 control panel 95 includes the following inputs: keyswitch to start the system and turn it off, standby and ready buttons to select the state of operation, controls to select fluence level, pulse width and repetition rate, and emergency-off button; and has the option of displaying the following information: laser and handpiece status (ready/not ready), laser emission indicator, and pulse counter.

20 In use, the operator first determines the general diameter of the hair to be removed from the patient. Then the laser-pulse duration is selected using the appropriate input 96. In one embodiment, typical hair shaft diameters of about 25 to 150 micrometers will result in laser-pulse durations of about 25 to 150 microseconds. The laser-pulse amplitude or laser-pulse fluence is also selected using an appropriate input 96. After
25 ensuring that the temperature of cooling surface 34 has reached the desired operating temperature, the front end 82 of cooling surface 34 is placed on the initial target area on the patient's skin. To ensure full treatment of the entire area of the skin without missing areas or having excessive overlaps in area, the skin area may be temporarily marked with a set of lines or a grid to help guide device 22. Front end 82 of cooling surface 34 is then
30 placed at a first target area on the patient's skin. Cooling surface 34 typically remains in place from about .25 to two seconds. In one preferred embodiment, cooling surface 34 remains in place for one second; after the first second, device 22 is moved in the direction of arrow 80 a distance equal to the length of window 46. After remaining at this position

for one second, the user again moves a distance equal to one window length. At this point the first target area has been cooled for the designed two seconds so the target area can be irradiated by pressing fire button 84 during the next one-second interval.

Following the firing of a laser and the expiration of the one-second interval, the operator
5 again moves device 22 in the direction arrow 80 one window length and presses fire button 84 to irradiate skin surface 6 thus causing thermal damage to hair tissue 20. The thermal damage is intended to cause the hair root area to be denatured so that the hair does not grow back. This procedure continues over the entire treatment area.

Modification and variation can be made to the disclosed embodiments
10 without departing from the subject of the invention as defined in the following claims. While the invention has been described primarily with reference to hair-treatment methods, it may also be useful for other dermatological application.

Any and all patents, patent applications and printed publications referred to above are incorporated by reference.

WHAT IS CLAIMED IS:

- 1 1. A hair removal device comprising:
2 a body having a skin-contacting end;
3 a skin-cooling element carried by the body and having a cooling surface at
4 the skin-contacting end;
5 a radiation source carried by the body and having a recessed window
6 through which hair tissue-damaging radiation passes to a patient's skin;
7 said recessed window being laterally offset from the cooling surface; and
8 said recessed window being spaced apart from the cooling surface in a
9 direction away from the patient's skin when the cooling surface is contacting the patient's
10 skin so to create a gap between the window and the patient's skin.
- 1 2. The device according to claim 1 further comprising a radiation
2 pulse actuator button carried by the body.
- 1 3. The device according to claim 1 wherein said radiation source
2 comprises an optical chamber having an exit aperture covered by said recessed window
3 and an optical fiber entrance in which an optical fiber can be housed to permit hair tissue-
4 damaging radiation to pass from the optical fiber into the optical chamber.
- 1 4. The device according to claim 3 wherein the exit aperture is
2 rectangular.
- 1 5. The device according to claim 4 wherein the exit aperture is square.
- 1 6. The device according to claim 3 wherein the optical chamber
2 comprises light-reflecting walls which help to equalize the fluence of radiation passing
3 through the exit aperture.
- 1 7. The device according to claim 3 wherein said optical chamber
2 comprises a total internal reflecting optical element having an entry surface facing the
3 optical fiber, an exit surface facing the recessed window and a total internal reflecting
4 sidewall surface so that effectively all radiation entering the entrance surface from the
5 optical fiber passes through the exit surface.

1 8. The device according to claim 7 wherein the optical element
2 comprises a rectangular fused silica block.

1 9. The device according to claim 3 wherein said optical chamber
2 comprises a beam size-defining lens system by which the lateral size of the radiation
3 beam passing through the recessed window can be controlled.

1 10. The device according to claim 3 further comprising a heating
2 element thermally coupled to the optical chamber so to permit heating of at least a part of
3 the optical chamber.

1 11. The device according to claim 10 further comprising a moisture-
2 wicking element extending between a region cooled by the skin-cooling element and the
3 heating element so that condensation at said region can be wicked away for evaporation
4 by the heating element.

1 12. The device according to claim 1 wherein the cooling surface is
2 adjacent to the recessed window and is aligned with the recessed window along a
3 direction of motion.

1 13. The device according to claim 12 wherein the recessed window and
2 the cooling surface have window and cooling surface dimensions along the direction of
3 motion.

1 14. The device according to claim 13 wherein the cooling surface
2 dimension is at least about two times the window dimension.

1 15. The device according to claim 13 wherein the cooling surface
2 dimension is about equal to the window dimension multiplied by a first chosen time
3 interval for cooling the patient's skin, the result divided by a second chosen time interval
4 between applications of the hair tissue-damaging radiation.

1 16. The device according to claim 1 wherein the window comprises an
2 inner window and an outer, user-replaceable window.

1 17. The device according to claim 15 further comprising an user-
2 removable clip releasably mounting the outer window to the body adjacent to the inner
3 window.

1 18. The device according to claim 1 wherein the body is a hand-
2 grippable body.

1 19. The device according to claim 1 wherein the cooling surface is a
2 high lubricity surface to help prevent bonding between the cooling surface and skin.

1 20. The device according to claim 1 further comprising a view port
2 formed adjacent to the recessed window to permit viewing of the patient's skin directly
3 under the recessed window.

1 21. The device according to claim 1 further comprising means for
2 viewing of the patient's skin directly under the recessed window.

1 22. The device according to claim 1 wherein the skin cooling element
2 comprises first and second of said cooling surfaces with the recessed window being
3 located between said first and second cooling surfaces.

1 23. A hair removal assembly comprising:
2 a body having a skin-contacting end;
3 a skin-cooling element carried by the body and having a cooling surface at
4 the skin-contacting end;
5 a radiation source carried by the body and having a window through which
6 hair tissue-damaging radiation passes to a patient's skin;
7 said window being laterally offset from the cooling surface;
8 a laser supplying laser light to the radiation source for passage through the
9 window; and
10 laser-power inputs comprising a laser-pulse duration input and one of a
11 laser-pulse amplitude input and a laser-pulse fluence input.

1 24. The assembly according to claim 23 wherein said window is a
2 recessed window spaced apart from the cooling surface in a direction away from the

3 patient's skin when the cooling surface is contacting the patient's skin so to create a gap
4 between the radiation source and the patient's skin.

1 25. The assembly according to claim 23 further comprising a source of
2 a liquid coolant, and wherein the cooling element comprises a heat sink, a coolant
3 evaporator thermally coupled to the heat sink, a coolant supply line coupling the coolant
4 evaporator to the source of liquid coolant, and a coolant vapor return line coupling the
5 evaporator to the source of liquid coolant.

1 26. The assembly according to claim 25 wherein the source of liquid
2 coolant comprises a refrigerant compressor.

1 27. The assembly according to claim 23 wherein the skin-cooling
2 element comprises a heat sink and a thermoelectric device having a cooled part, thermally
3 coupled to the heat sink, and a heated part.

1 28. The assembly according to claim 27 wherein the heated part of the
2 thermoelectric device is thermally coupled to a second heat sink.

1 29. The assembly according to claim 28 wherein the second heat sink
2 is a liquid-cooled heat sink.

1 30. The assembly according to claim 23 further comprising a heating
2 element thermally coupled to the radiation source.

1 31. The assembly according to claim 30 further comprising a moisture-
2 wicking element extending between a region cooled by the skin-cooling element and the
3 heating element so that condensation at said region can be wicked away for evaporation
4 by the heating element.

1 32. The assembly according to claim 31 wherein the heating element
2 comprises a heat sink portion and said wicking element is in contact with the heat sink
3 portion of the heating element.

1 33. The assembly according to claim 23 wherein said radiation source
2 comprises an optical chamber having an exit aperture covered by said window and an

3 optical fiber entrance in which an optical fiber is housed to permit laser light from the
4 laser to be directed into the optical chamber, and further comprising a heating element
5 thermally coupled to the optical chamber to help prevent condensation on said optical
6 chamber or said window.

1 34. The assembly according to claim 33 wherein the heating element
2 comprises a heat sink portion in physical contact with the optical chamber.

1 35. The assembly according to claim 26 wherein said optical chamber
2 comprises a total internal reflecting optical element having an entry surface facing the
3 optical fiber, an exit surface facing the recessed window and a total internal reflecting
4 sidewall surface so that effectively all radiation entering the entrance surface from the
5 optical fiber passes through the exit surface.

1 36. The assembly according to claim 35 wherein the optical element
2 comprises a rectangular fused silica block.

1 37. The assembly according to claim 26 wherein said optical chamber
2 comprises a beam size-defining lens system by which the lateral size of the radiation
3 beam passing through the recessed window can be controlled.

1 38. The assembly according to claim 26 further comprising a moisture
2 wicking element extending between a region cooled by the skin-cooling element and the
3 heating element so that condensation at said region can be wicked away for evaporation
4 by the heating element.

1 39. A hair-removal method comprising:
2 determining the diameter typical of the hair to be removed from a patient;
3 selecting a laser-pulse duration for a hair removal device according to this
4 diameter of the hair so that smaller diameter hair results in a shorter laser-pulse duration
5 than larger diameter hair; and
6 applying laser energy through a window of the hair removal device of the
7 selected laser-pulse duration to a patient's skin to cause thermal injury to hair tissue.

1 40. A method for preparing a hair-removal device for use comprising:

2 determining the diameter typical of the hair to be removed from a patient;
3 and
4 selecting a laser-pulse duration for a hair removal device according to this
5 diameter of the hair so that smaller diameter hair results in a shorter laser-pulse duration
6 than larger diameter hair.

1 41. The method according to claims 39 or 40 further comprising the
2 step of selecting a chosen one of a laser-pulse amplitude and a laser-pulse fluence prior to
3 the applying step.

1 42. The method according to claim 39 wherein the laser energy
2 applying step is carried out by:
3 positioning a cooling element of the hair removal device against a first
4 target area on the patient's skin;
5 moving, after a chosen cooling period of time, the cooling element from
6 the first target area to a second target area with the window overlying and spaced-apart
7 from the first target area;

8 applying the laser energy to the first target area through the window with
9 the window overlying and spaced-apart from the first target area

1 43. The method according to claim 42 further comprising moving, after
2 the laser energy applying step, the window to overlay the second target area while
3 positioning a second cooling surface against the first target area.

1 44. The method according to claim 42 wherein the moving step is
2 carried out with the chosen cooling period of time being about .25 to two seconds.

1 45. The method according to claims 39 or 40 further comprising the
2 step of selecting a hair removal device using laser energy in the 800 to 1200nm wavelength
3 range.

1 46. The method according to claims 39 or 40 further comprising the
2 step of selecting a hair removal device using laser energy having a wavelength of about
3 1.06 microns.

1 47. The method according to claims 39 or 40 wherein the selecting step
2 is carried out so that hair diameters from about 25 to 150 micrometers result in laser-pulse
3 durations of about 5 to 50 milliseconds.

1 48. A method for preparing to apply hair tissue-damaging radiation to a
2 target site on a patient's skin comprising:

3 accessing a hair removal device having a skin cooling surface and a
4 radiation source with a window through which hair tissue-damaging radiation passes, the
5 skin cooling surface and the window aligned along a direction of motion;

6 selecting a chosen one of :

7 (i) a first chosen time interval (C) for cooling the target site; and

8 (ii) a second chosen time interval (Z) between applications of hair
9 tissue-damaging radiation; and

10 determining the other of the first and second time intervals based on the
11 following:

12 $Y = (X \times C) / Z$, where

13 X and Y are the respective lengths of the cooling surface and the
14 window measured in the direction of motion.

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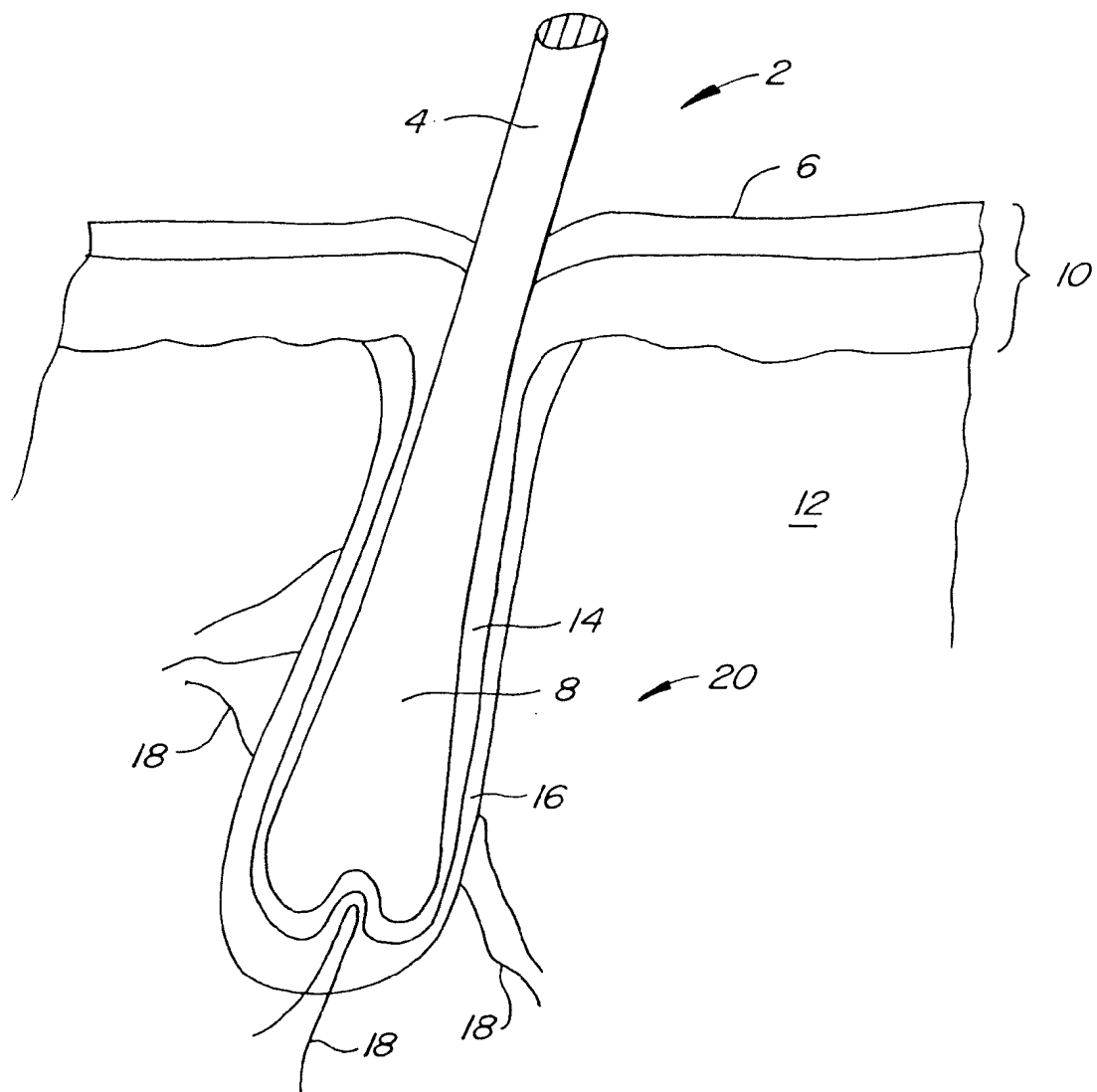


FIG. 1.

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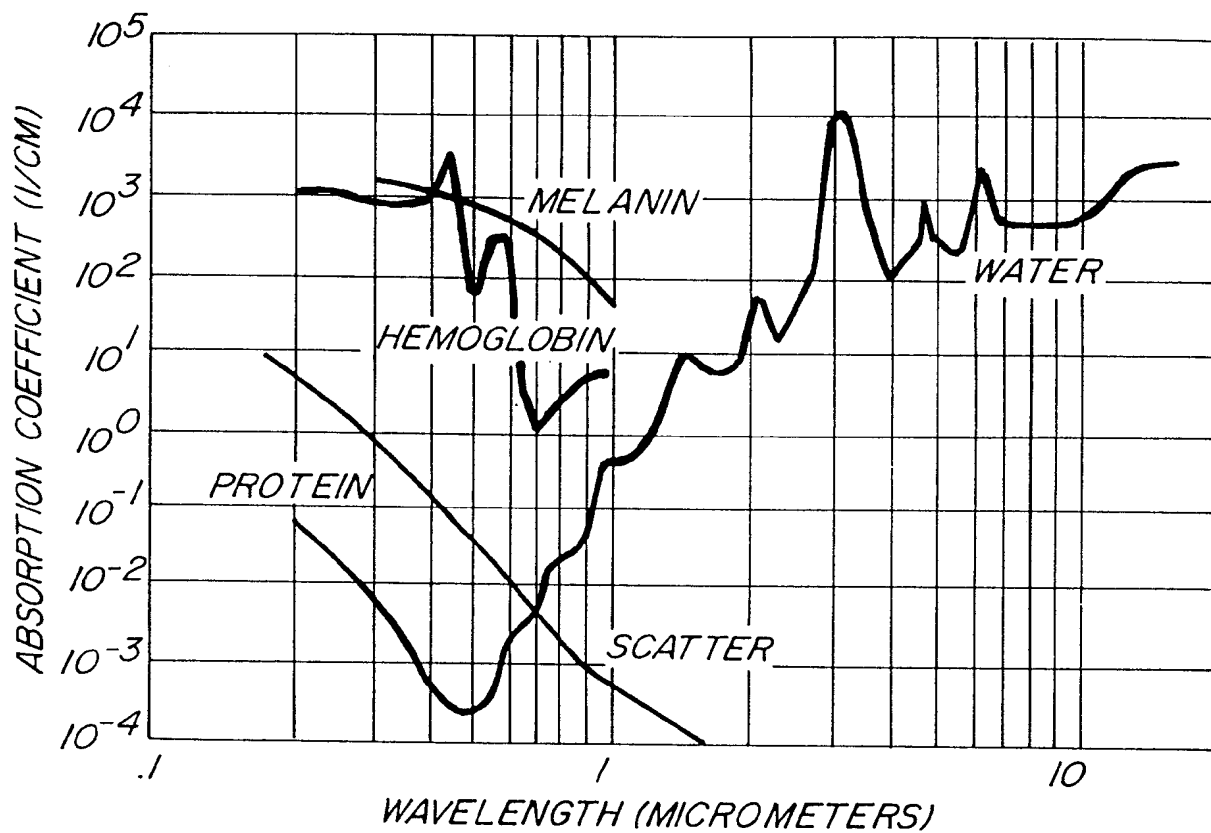


FIG. 2.

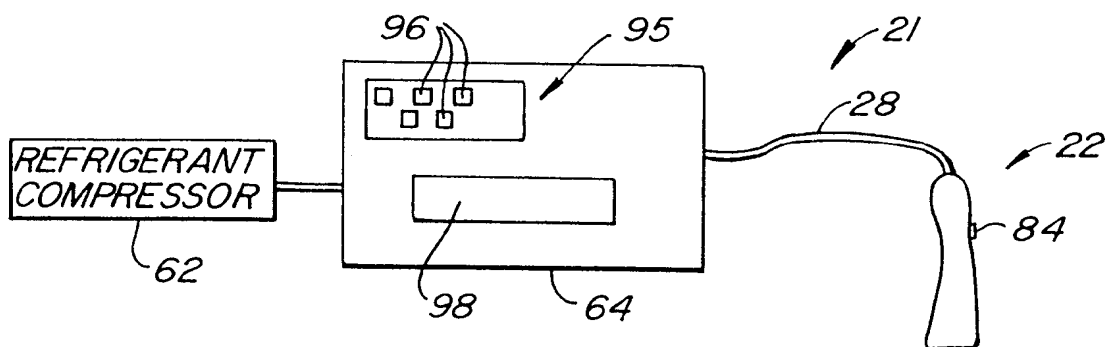


FIG. 3.

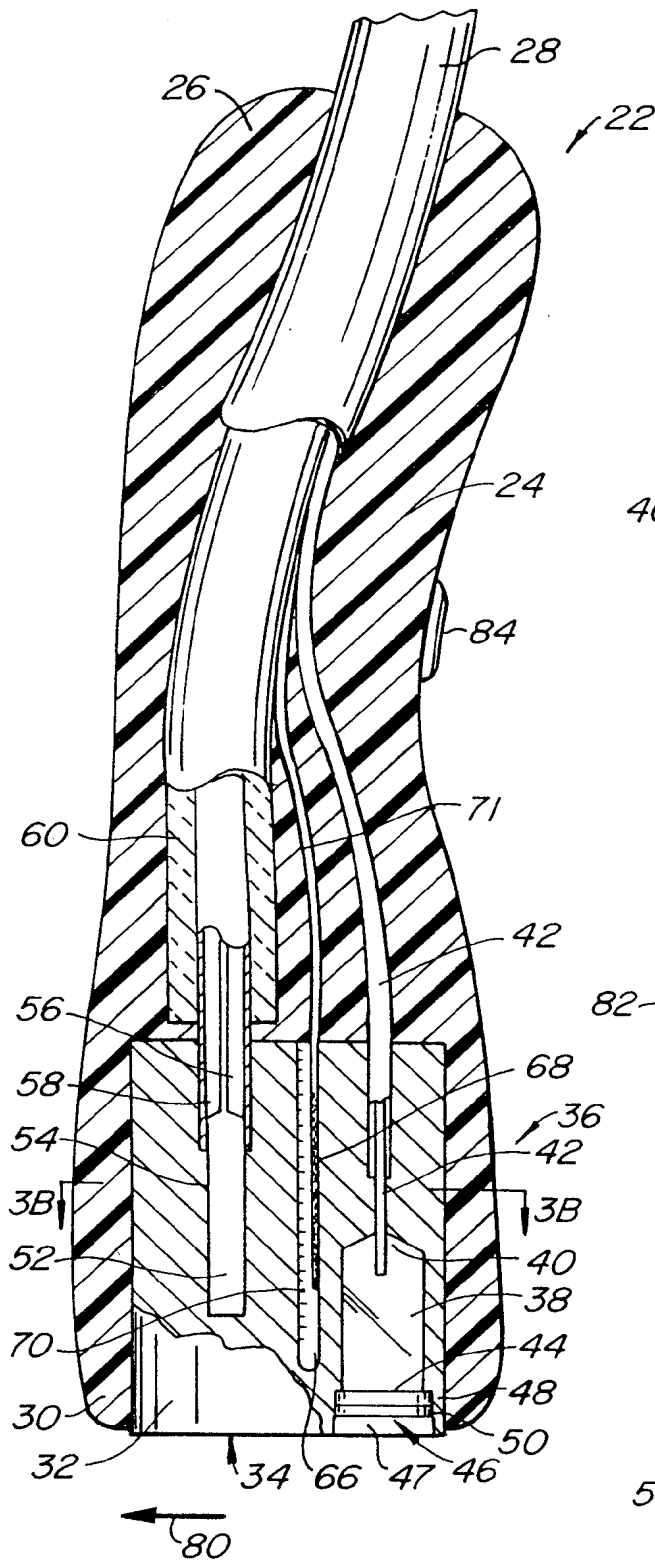


FIG. 3A.

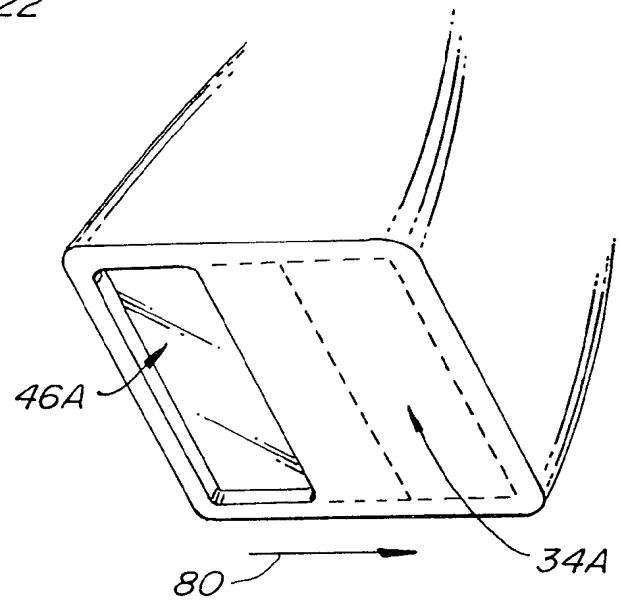


FIG. 4A.

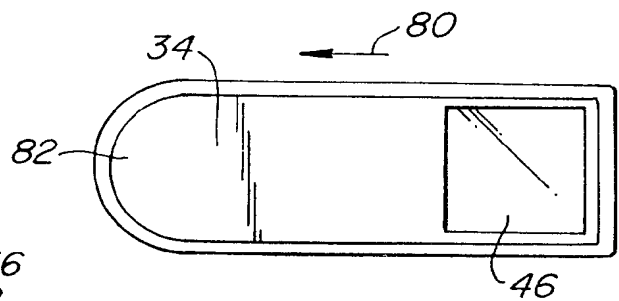


FIG. 4.

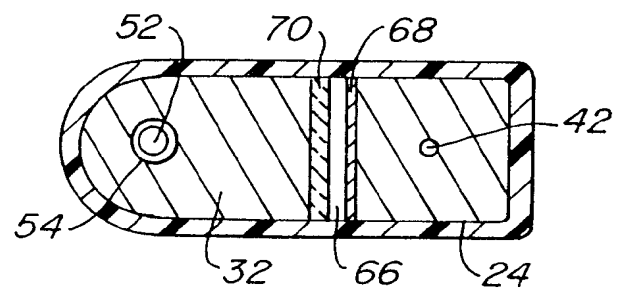


FIG. 3B.

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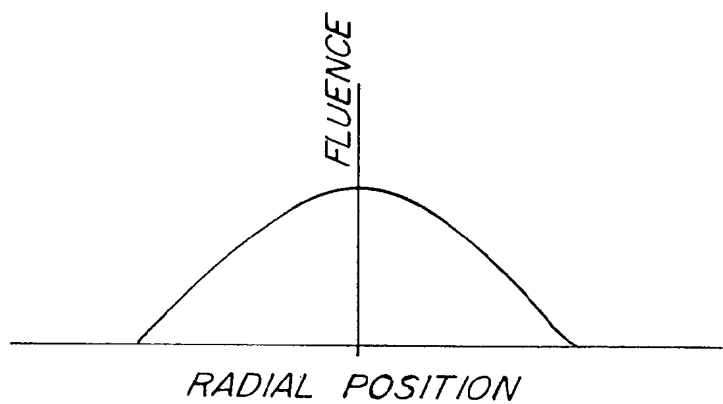


FIG. 5.

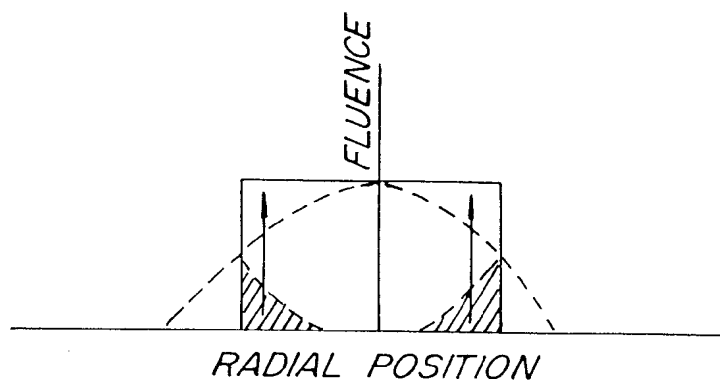


FIG. 5A.

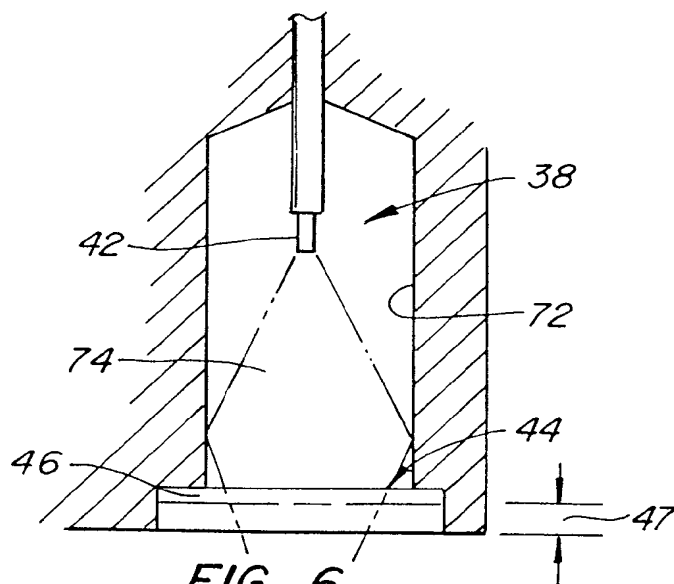


FIG. 6.

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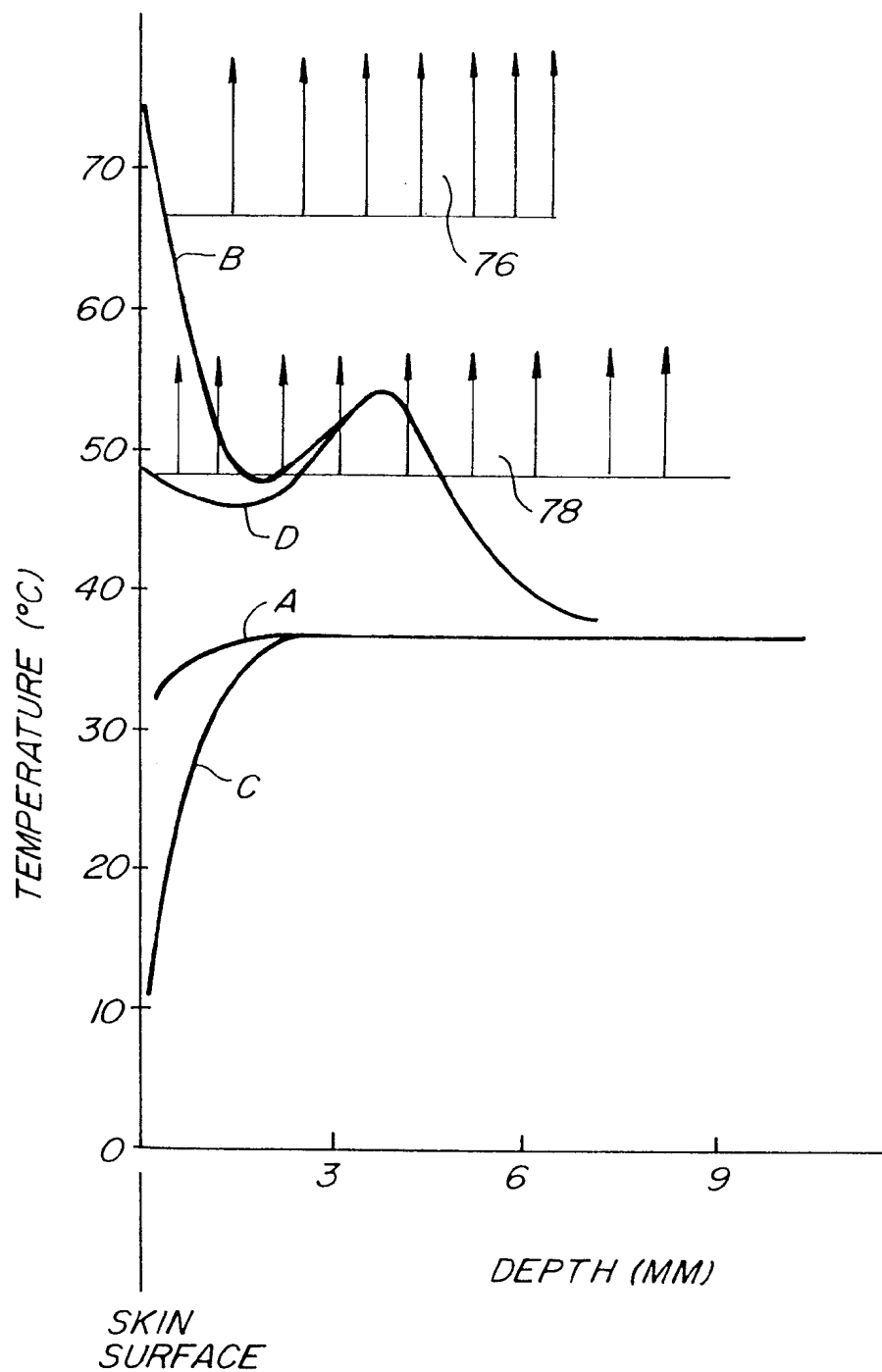


FIG. 7.

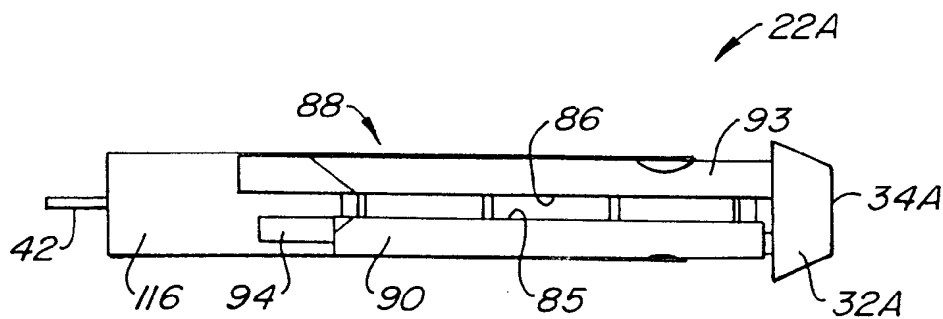


FIG. 8C.

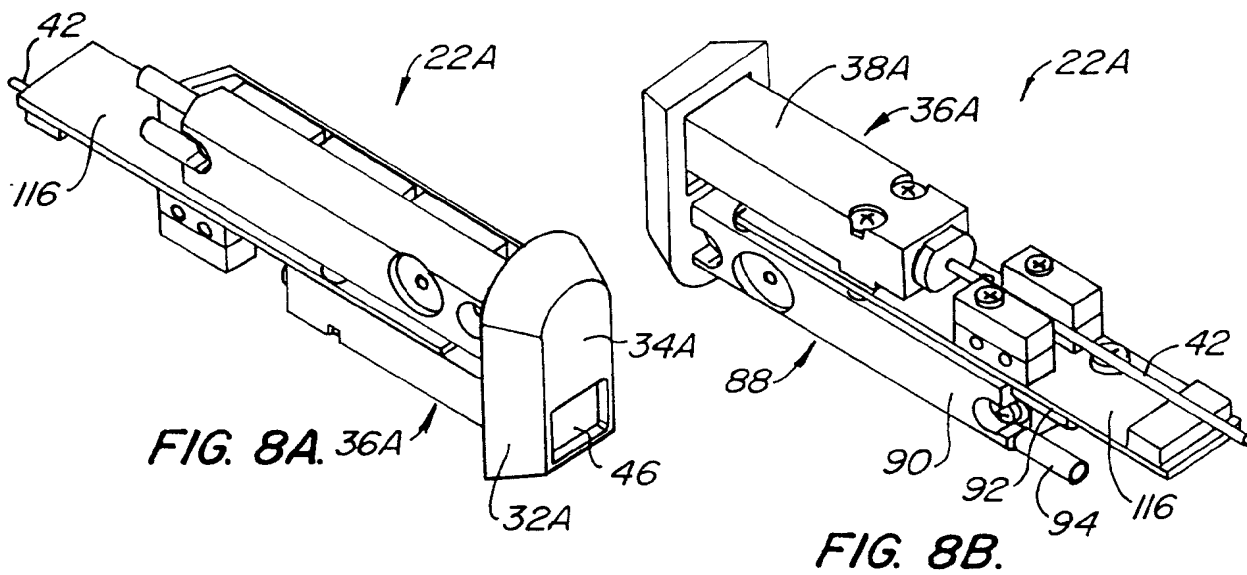


FIG. 8A.

FIG. 8B.

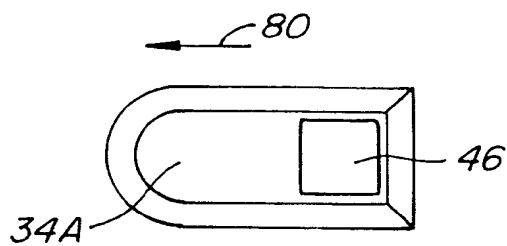


FIG. 8D.

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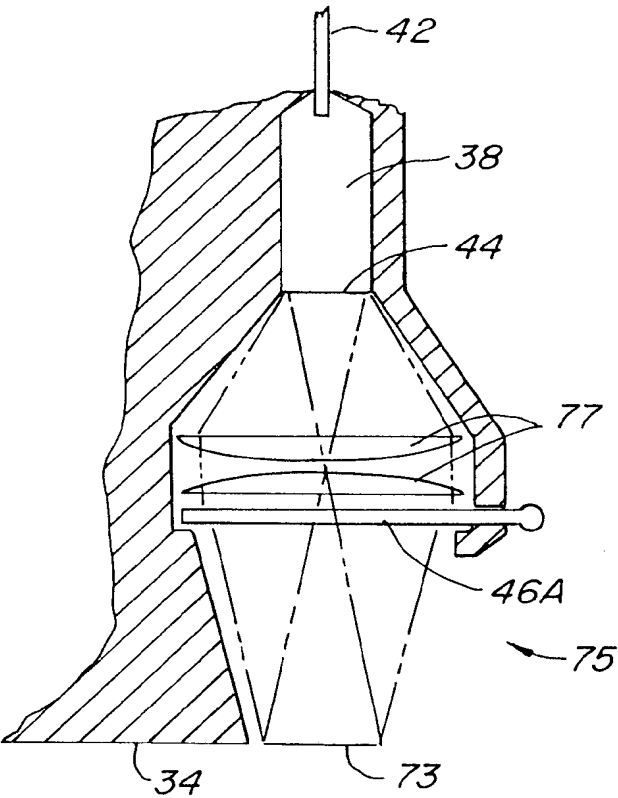


FIG. 9.

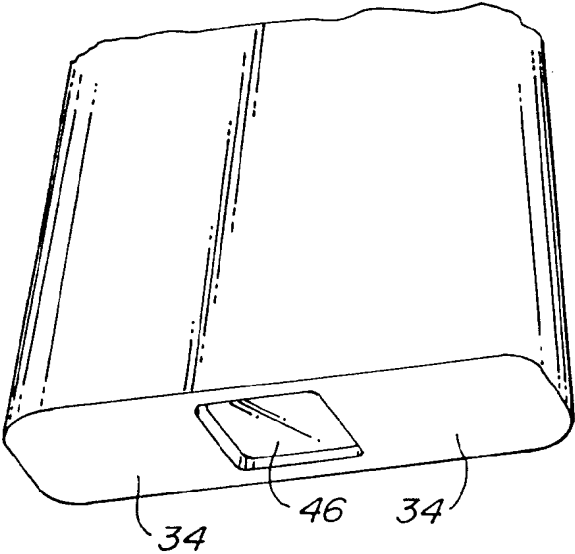


FIG. 10.

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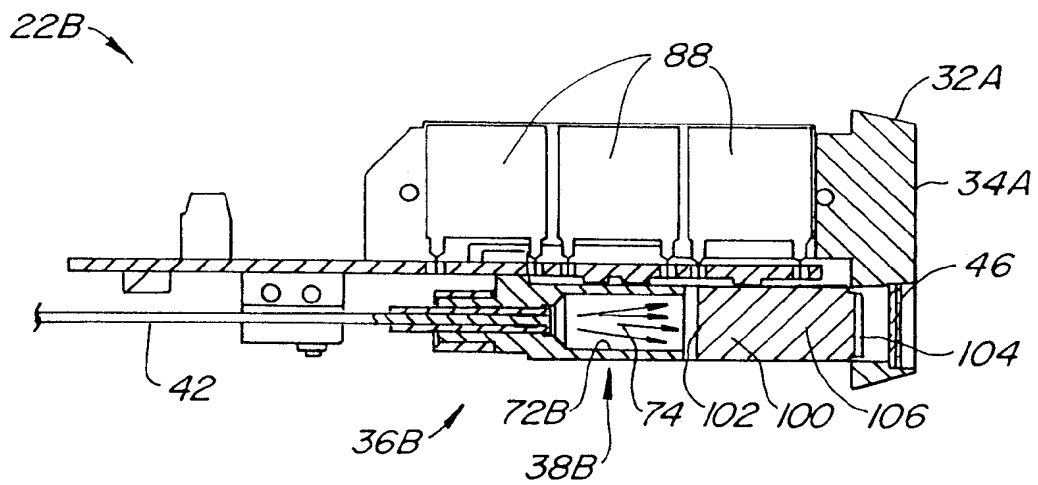


FIG. 11.

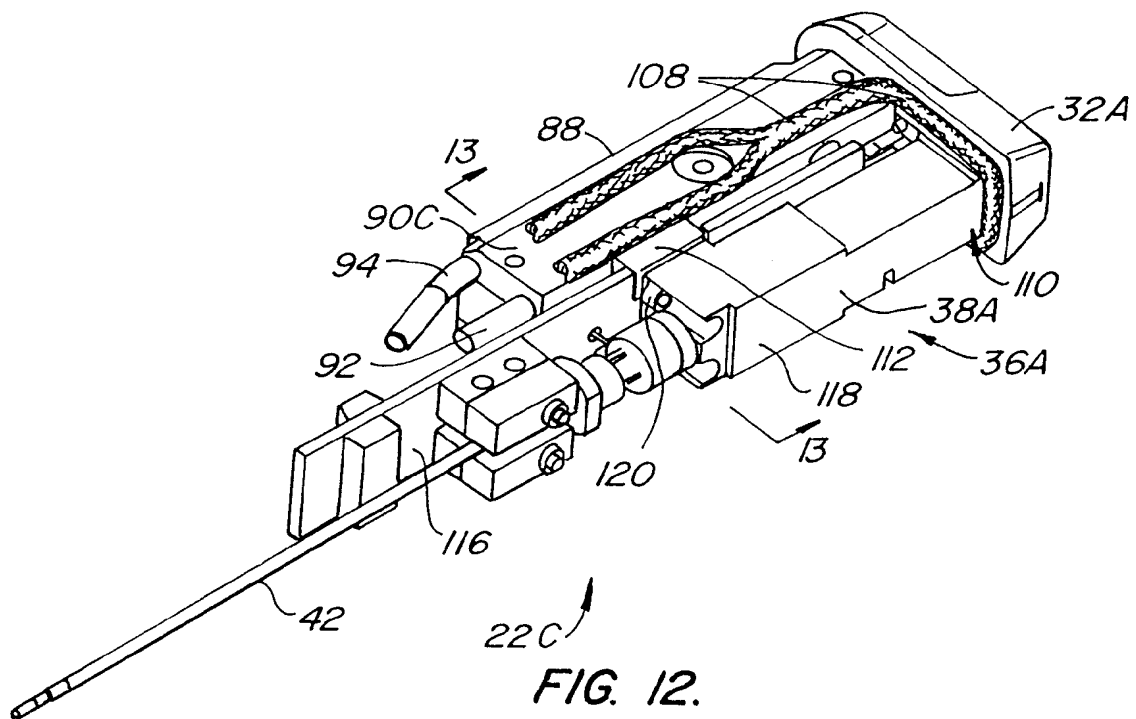


FIG. 12.

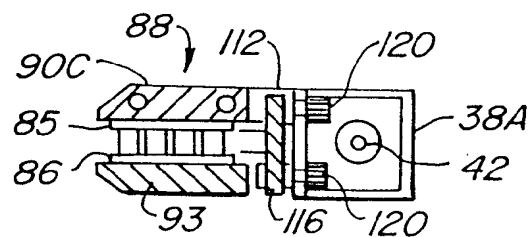


FIG. 13.

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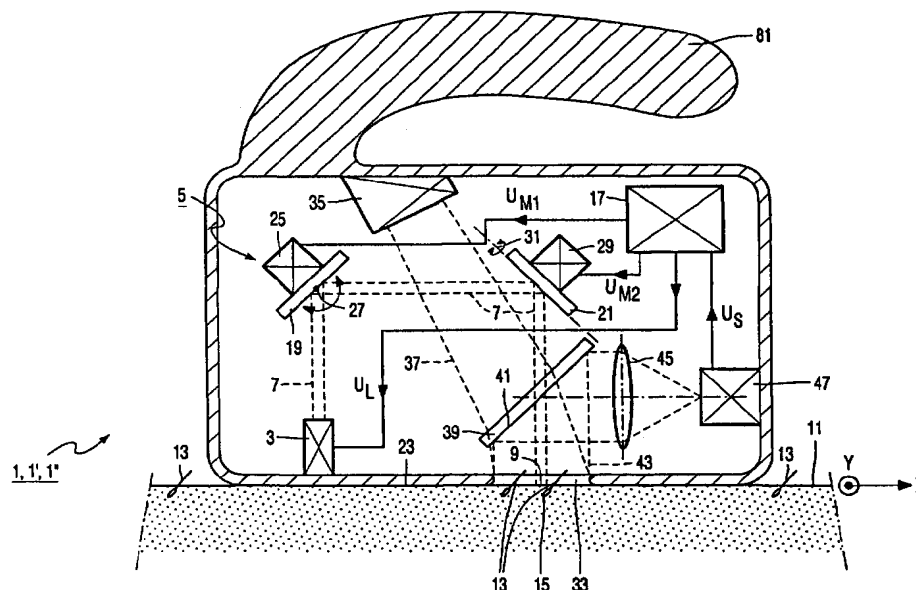
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<p>(21) International Application Number: PCT/EP00/02871</p> <p>(22) International Filing Date: 3 April 2000 (03.04.00)</p> <p>(30) Priority Data: 99201169.2 14 April 1999 (14.04.99) EP</p> <p>(71) Applicant: KONINKLIJKE PHILIPS ELECTRONICS N.V. [NL/NL]; Groenewoudseweg 1, NL-5621 BA Eindhoven (NL).</p> <p>(72) Inventors: LEFKI, Karim, M., T.; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). CENSE, Abraham, J.; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). CHENG, Xiang, S.; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). VAN AMSTEL, Willem, D.; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). VELDHUIS, Gerrit, J.; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL).</p> <p>(74) Agent: WOLFS, Marc, J., M.; Internationaal Octrooibureau B.V., Prof Holstlaan 6, NL-5656 AA Eindhoven (NL).</p>		<p>(81) Designated States: IL, JP, MX, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).</p> <p>Published <i>With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p>

(54) Title: HAIR-REMOVING DEVICE WITH A CONTROLLABLE LASER SOURCE

(57) Abstract

A hair-removing device (1) comprises a laser source (3), an adjustable laser beam manipulator (5) for positioning a laser beam (7) of the laser source (3) in a target position (9) on a skin (11) to be treated, and an image sensor (47) for detecting an image (49) of the skin. According to the invention, the hair-removing device further comprises a control unit (17) which determines a position and orientation on the skin of a hair (13) to be removed, and which determines the target position of the laser beam as a function of said position and orientation of the hair. The control unit brings the laser beam manipulator in a state corresponding to the target position of the laser beam, and activates the laser source when the laser beam manipulator has reached said state. Thus, the hair-removing device is suitable for use by inexperienced users, and is particularly suitable for the consumer market.

In a particular embodiment, the control unit determines the target position of the laser beam in a position (71) on the skin under which a root (15) of the hair is present, so that the root of the hair is destroyed and the hair-removing device (1) is an epilating device by means of which the hair is removed for a relatively long time or even permanently. In another embodiment, the control unit determines the target position of the laser beam in a position (65) on the hair where the hair comes out of the skin, so that the hair is burnt through near the skin surface and the hair-removing device (1'') is a shaving device by means of which a high skin smoothness is obtained.



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Hair-removing device with a controllable laser source.

The invention relates to a hair-removing device provided with a laser source, an adjustable laser beam manipulator for positioning a laser beam supplied by the laser source during operation in a target position on a skin to be treated, and an image sensor for detecting an image of at least a portion of the skin.

5

A hair-removing device of the kind mentioned in the opening paragraph is known from US patent 5,653,706. The known hair-removing device is designed for use by a professional therapist and may be used not only for removing hairs but also for other dermatological treatments such as the treatment of necrotic skin tissue, varicose veins, or pigment spots. The image of the skin detected by the image sensor is rendered visible to the therapist on a picture screen. The known hair-removing device further comprises a control member by means of which the therapist can operate the laser beam manipulator and can thus guide the laser beam supplied by the laser source manually over the skin under treatment. While being guided over the skin, the laser beam has only a comparatively low energy density, and the therapist can monitor the position of the laser beam on the skin by means of the picture screen. When the laser beam is in the target position as determined by the therapist, the laser beam can be intensified for a predetermined time duration by the therapist through the operation of a further control member of the hair-removing device. The laser beam has a wavelength which is well absorbed by the tissue to be treated, so that the tissue present around the target position is strongly heated locally by the laser beam, and the relevant tissue dies. For a permanent removal or epilation of a hair present on the skin, the laser beam is aimed at the root of the hair, so that the root and the tissue surrounding it die. Since the known hair-removing device is provided with said image sensor and adjustable laser beam manipulator, it is possible to treat the skin locally with a laser beam of a comparatively small spot diameter, so that the laser source need have only a comparatively low power. Accordingly, a comparatively small and simple laser diode is used in the known hair-removing device.

A disadvantage of the known hair-removing device is that a comparatively long treatment time is necessary for the removal of all hairs present on a skin under treatment because the therapist must displace the laser beam manually from one hair to the next. In

addition, a determination of the target position of the laser beam on the skin requires the user to have a considerable experience, so that the known hair-removing device is suitable exclusively for use by a professional therapist.

5 It is an object of the invention to provide a hair-removing device of the kind mentioned in the opening paragraph with which a comparatively short treatment time is possible and which is suitable for use by inexperienced persons, i.e. suitable for the consumer market.

10 To achieve this object, a hair-removing device according to the invention is characterized in that the laser source is controllable by means of an electrical control unit, which control unit during operation determines the target position of the laser beam as a function of a position and/or orientation on the skin of a hair to be removed as determined from the image by the control unit, and which control unit activates the laser source the moment the laser beam manipulator is in a position which corresponds to the target position of the laser beam. The determination of the target position of the laser beam and the activation of the laser source take place fully automatically because the target position of the laser beam is determined by the control unit and the laser source is activated by the control unit when the laser beam manipulator is in a position which corresponds to the target position of the laser beam. The control unit also renders it possible, for example, to adjust the laser beam manipulator in a predetermined manner automatically in that position which corresponds to the target position of the laser beam on the skin. This renders the hair-removing device according to the invention suitable for a safe use by inexperienced persons, so that the hair-removing device is particularly suitable for the consumer market. The control unit comprises, for example, a suitable algorithm for determining the target position for the laser beam from the image of the skin detected by the image sensor, which algorithm is capable of determining the position and/or the orientation of the hair to be removed on the skin on the basis of the image information and is capable of determining the target position on the basis of said position and/or orientation of the hair. The automatic determination of the target position of the laser beam as described above, the automatic adjustment of the laser beam manipulator, and the automatic activation of the laser source take place within a comparatively short time, so that a comparatively short treatment period can be achieved by means of the hair-removing device according to the invention.

 A special embodiment of a hair-removing device according to the invention is characterized in that the control unit determines the target position of the laser beam in a

partial region of the image having dimensions which are determined by a previously determined average distance between hairs present on the skin and a previously determined length of the hairs. In this special embodiment, the control unit is active substantially exclusively in said partial region of the image which comprises no more than a few hairs to be removed, and preferably only a single hair. Said previously determined length of the hairs should preferably be smaller than said average distance between the hairs and can be achieved, for example, in that the hairs are trimmed by means of a separate trimmer or, for example, a trimmer belonging to the hair-removing device prior to the treatment by means of the hair-removing device. Since the control unit is active substantially exclusively in said partial region of the image, a calculation time and calculation capacity of the control unit required for determining the target position are strongly reduced.

A further embodiment of a hair-removing device according to the invention is characterized in that the dimensions of the partial region of the image are adjustable. Since the dimensions of the partial region of the image are adjustable, said dimensions can be adapted to the properties of the skin under treatment by the user of the hair-removing device, so that the treatment time and treatment result can be optimized for each individual user.

A yet further embodiment of a hair-removing device according to the invention is characterized in that the laser beam manipulator is adjustable by means of the control unit into a sequence of consecutive positions which correspond to a regular sequence of virtual positions of the laser beam on said portion of the skin, a reference position in the partial region of the image corresponding to the instantaneous virtual position of the laser beam, and the control unit activating the laser source when the reference position corresponds to the target position of the laser beam. In this yet further embodiment, the portion of the skin corresponding to the image is scanned by the laser beam manipulator in a regular manner.

Since the reference position lying in the partial region of the image corresponds to the instantaneous virtual position of the laser beam, the partial region of the image will follow the instantaneous virtual position of the laser beam, so that the target position in the partial region of the image as determined by the control unit changes continually with respect to the reference position. An advantage of this yet further embodiment is that the laser beam manipulator is continuously justed in a regular manner by the control unit, so that the laser beam manipulator need not have an exceptionally short adjustment time and an exceptionally high adjustment accuracy.

A special embodiment of a hair-removing device according to the invention is characterized in that the control unit determines the target position of the laser beam in a

regular sequence of consecutive partial regions of the image, the laser beam manipulator being adjustable by means of the control unit in each of said partial regions into a position which corresponds to the target position of the laser beam in the relevant partial region. In this special embodiment, the detected image of the skin is scanned by the control unit in a regular manner in accordance with said sequence of consecutive partial regions. The control unit determines a target position in each of the consecutive partial regions, whereupon the laser beam manipulator is adjusted into the position corresponding to the relevant target position by the control unit. An advantage of this special embodiment is that the laser beam manipulator need not scan the full portion of the skin which corresponds to the image but is merely adjusted consecutively into positions which correspond to the target positions as determined in the consecutive partial regions of the image. It is true that the laser beam manipulator is adjusted in an irregular manner by the control unit here, so that comparatively high requirements are imposed on the adjustment time and the adjustment accuracy of the laser beam manipulator, but the treatment time of the hair-removing device is considerably further reduced.

A further embodiment of a hair-removing device according to the invention is characterized in that the control unit determines from the position and orientation on the skin of the hair to be removed, as determined from the image, a region on the skin below which a root of the hair will be present with a predetermined degree of probability, the control unit determining at least one target position on the skin in said region. In this further embodiment, the hair-removing device is used as an epilation device. Since the laser beam treats the root of the hair, the root of the hair will die, as will the skin tissue present in the immediate vicinity, so that the hair is permanently removed, or at least for a longer period. The region on the skin below which the root is deemed to be present with the predetermined degree of probability is determined by the control unit on the basis of, for example, previously determined statistical information on the length of the subcutaneous portions of hairs and on the angle of the subcutaneous portions of hairs with respect to the skin surface.

A yet further embodiment of a hair-removing device according to the invention is characterized in that the laser beam manipulator is adjustable by means of the control unit into a sequence of consecutive positions which correspond to a displacement of the laser beam over a rectilinear path on the skin with a predetermined velocity, said rectilinear path lying on a virtual straight line which coincides substantially with a perpendicular projection of the hair to be removed on the skin, the control unit activating the laser source at the start of said displacement. The region on the skin mentioned above below which the root of the hair will be

present with the predetermined degree of probability can thus be efficiently treated in its entirety, while a required spot diameter of the laser beam is considerably reduced.

A particular embodiment of a hair-removing device according to the invention is characterized in that the laser beam manipulator is adjustable by means of the control unit
5 into a number of consecutive fixed positions corresponding to a number of fixed target positions of the laser beam on a rectilinear path on the skin, which rectilinear path lies on a virtual straight line which coincides substantially with a perpendicular projection of the hair to be removed on the skin, the control unit activating the laser source in each of said fixed positions of the laser beam manipulator during a predetermined time. Said region on the skin
10 below which the root of the hair will be present with the predetermined degree of probability can thus likewise be efficiently treated in its entirety, while a required spot diameter of the laser beam is likewise strongly reduced.

A further embodiment of a hair-removing device according to the invention is characterized in that the control unit determines an exit position on the hair, where the hair
15 issues from the skin, from the position and orientation on the skin of the hair to be removed as determined from the image, the control unit equalizing the target position of the laser beam with a position on the hair adjacent said exit position. This further embodiment of the hair-removing device is used as a shaver. Since the target position of the laser beam lies on the hair adjacent the exit position of the hair, the hair will be burnt through by the laser beam adjacent
20 the exit position, i.e. adjacent the skin surface. The control unit may be programmed, for example, such that the target position lies at a level with the skin surface, or even below the skin surface, so that a very smooth shaving result is obtained which is maintained for a comparatively long period. The hair-removing device may be provided, for example, with a further adjustment member for adjusting the target position relative to the skin surface, so that
25 the user can set a desired smoothness.

A still further embodiment of a hair-removing device according to the invention is characterized in that the hair-removing device comprises a separate illumination member for illuminating at least the portion of the skin which is to be detected by the image sensor. The use of the separate illumination member achieves that the image detected by the image sensor
30 is fully formed by light from the illumination member reflected by the skin, and the laser source can be completely switched off between the exposures of two consecutive target positions. Reflected light coming from the laser beam need not reach the image sensor because the image detected by the image sensor is fully formed by light of the illumination member reflected by the skin. Accordingly, the image sensor may be provided with a filter for the

reflected light of the laser beam, so that the image sensor is protected against damage which may arise as a result of the reflected light of the laser beam when the laser beam is in its target position and has a high energy density.

5 A special embodiment of a hair-removing device according to the invention is characterized in that the control unit determines from the image a reflection spectrum of the skin portion detected by the image sensor, the control unit comparing the reflection spectrum with a predetermined reference spectrum of at least one frequently occurring skin deviation, while the control unit determines from said comparison positions on the skin in which said skin deviation is present and does not activate the laser source in said positions on the skin. It is prevented in this special embodiment that the laser beam is aimed at target positions which lie within such a skin deviation such as, for example, a mole or some other pigment spot. Such skin deviations often have a comparatively high absorption power for the laser light used for the treatment of the hairs or hair roots, so that injuries arise in the case of contact with laser light. This special embodiment thus provides an automatic protection from such injuries.

15 A further embodiment of a hair-removing device according to the invention is characterized in that the control unit comprises means for determining an actual position of the laser beam on the skin from the image detected by the image sensor. Since the actual position of the laser beam on the skin is determined, the laser beam manipulator can, for example, be corrected or calibrated in such a manner that said actual position accurately corresponds with the desired target position determined by the control unit. Since said actual position is determined by the image sensor, a separate sensor for determining said actual position is not necessary, and the image sensor is used in an effective manner.

25 A yet further embodiment of a hair-removing device according to the invention is characterized in that the laser beam manipulator is adjustable by means of the control unit via an output signal of the control unit in accordance with a predetermined mathematical relation between said output signal and the target position, the control unit comprising a calibration member for calibrating said predetermined mathematical relation on the basis of a measured relation between said output signal and the actual position of the laser beam on the skin. Since the control unit adjusts the laser beam manipulator in accordance with said predetermined mathematical relation between said output signal and the target position, the output signal required to achieve a predetermined target position can be determined by the control unit in a relatively short time period, so that the predetermined target position is achieved in a relatively short time period. Since said mathematical relation is calibrated on the basis of a measured relation between said output signal and said actual position, the laser beam

is very accurately positionable in the target position by the laser beam manipulator, so that damage of the skin around the target position by the laser beam is prevented as much as possible, and the target position is not missed by the laser beam.

A particular embodiment of a hair-removing device according to the invention is characterized in that, for determining the actual position of the laser beam on the skin, the control unit activates the laser source at a comparatively low energy density. When the laser source is activated at a low energy density, the laser beam generates a spot on the skin which is sufficiently bright to be detected by the image sensor, but which does not damage nor irritate the skin. Thus, the actual position of the laser beam on the skin can be determined by the control member of the control unit in a safe and reliable manner, and the energy consumption of the laser source is considerably limited.

The invention will be explained in more detail below with reference to the drawing, in which

Fig. 1 diagrammatically shows a hair-removing device according to the invention,

Fig. 2 is a diagrammatic cross-section of a skin to be treated adjacent a hair which is to be removed by means of the hair-removing device of Fig. 1,

Fig. 3 diagrammatically shows an image of a portion of a skin under treatment which is detected by means of an image sensor of the hair-removing device of Fig. 1,

Fig. 4 diagrammatically shows a control unit of the hair-removing device of Fig. 1,

Fig. 5a diagrammatically shows a partial region of the image of Fig. 3,

Fig. 5b diagrammatically shows a partial region of the image of Fig. 3 in an alternative embodiment of a hair-removing device according to the invention,

Fig. 6 shows a reflection spectrum determined by the control unit of Fig. 4 from the image of Fig. 3,

Fig. 7 diagrammatically shows a control unit of a further embodiment of a hair-removing device according to the invention,

Fig. 8 diagrammatically shows a partial region of a detected image of the skin under treatment generated by the control unit of Fig. 7, and

Fig. 9 diagrammatically shows a partial region of an image of the skin under treatment generated by a control unit of a yet further embodiment of a hair-removing device according to the invention.

The hair-removing device 1 according to the invention diagrammatically shown in Fig. 1 comprises a laser source 3 and an adjustable laser beam manipulator 5 for positioning a laser beam 7 supplied during operation by the laser source 3 in a target position 9 on a skin 11 to be treated. The hair-removing device 1 is an epilation device by means of which hairs 13 present on the skin 11 can be removed for a comparatively long period or even permanently. If a hair 13 is to be epilated, the target position 9 of the laser beam 7 must be approximately in a position on the skin 11 below which a root 15 of the hair 13 is present, as is diagrammatically shown in Fig. 2. The laser beam 7 contains monochromatic light with a wavelength which is well absorbed by the hair 13 and is substantially not absorbed by tissue of the skin 11. The result of this is that it is substantially exclusively the root 15 of the hair 13 which is strongly heated by the laser beam 7, so that the root 15 dies. A good optical selectivity between the hairs 13 and the tissue of the skin 11 is achieved with a wavelength between approximately 650 nm and 1200 nm in the case of a white skin with dark hairs. Light with such a wavelength is well absorbed by melanin, a pigment which occurs in a high concentration in dark hairs and only in a low concentration in a white skin. Light with such a wavelength is also badly absorbed by water, by hemoglobin, a red pigment which occurs in a high concentration in blood, and by keratin, a substance which occurs in a high concentration in both the outer skin (epidermis) and in the skin tissue which occurs at a lower depth in the skin, where the roots 15 of the hairs 13 are present. A sufficient pulse duration and energy density of the laser beam 7 are furthermore necessary for achieving an effective operation of the hair-removing device 1. A too short pulse duration leads merely to a heating of the root 15 and not to a heating of the tissue present in the immediate vicinity of the root 15. The result is that said tissue remains intact, so that a new root and hair can develop. A too long pulse duration leads to an excessive heating of the tissue present at some distance from the root 15 owing to thermal conduction, which may give rise to skin irritation or even skin damage. Good results are obtained with a pulse duration of the laser beam 7 of between approximately 1 ms and 100 ms and an energy density of the laser beam 7 of between approximately 15 J/cm^2 and 50 J/cm^2 .

The laser beam 7 can be accurately positioned in the target position 9 by means of the laser beam manipulator 5 in a manner to be described in more detail below, while the target position 9 can be accurately determined by means of an electrical control unit 17 of the hair-removing device 1 in a manner to be described in more detail below. As a result, the laser beam 7 need have only a comparatively small spot diameter for heating the root 15. Good results are obtained at a spot diameter of the laser beam 7 of between approximately 0.3 mm and 1.0 mm. This comparatively small spot diameter means that the laser source 3 need have

only a comparatively low output power of a few watts for achieving the required energy density and pulse duration of the laser beam 7. The laser source 3 used in the hair-removing device 1 accordingly comprises only a comparatively small and simple laser diode which is known per se and which is not shown in detail in Fig. 1, or a series of fiber-coupled laser diodes which are known per se and are also not shown in detail in Fig. 1. The laser source 3 further comprises a collimator lens system which is also not shown in Fig. 1 and by means of which the laser beam 7 is directed so as to be substantially parallel.

As Fig. 1 further shows, the laser beam manipulator 5 comprises a first adjustable tilting mirror 19 and a second adjustable tilting mirror 21 which are both positioned at an angle of approximately 45° with respect to a contact surface 23 with which the hair-removing device 1 is to be laid against the skin 11. The first tilting mirror 19 is tiltable through limited angles about a first tilting axis 21 extending in the plane of the first tilting mirror 19 and parallel to the contact surface 23 by means of an actuator 25 which is depicted diagrammatically only in Fig. 1. The second tilting mirror 21 is tiltable through limited angles about a second tilting axis 31 lying in the plane of the second tilting mirror 21 and crossing the first tilting axis 27 approximately perpendicularly by means of an actuator 29 which is also depicted diagrammatically only in Fig. 1. The laser beam 7 supplied by the laser source 3 during operation is reflected by the first tilting mirror 19 and the second tilting mirror 21 through angles of approximately 45° , so that the laser beam 7 hits the skin 11 under treatment substantially perpendicularly in the target position 9 through an opening 33 provided in the contact surface 23. It is noted that the opening 33 may be covered by means of a cover plate of a transparent material. The target position 9 of the laser beam 7 on the skin 11 is displaceable parallel to an X-direction, which lies in the contact surface 23 and which crosses the first tilting axis 27 perpendicularly, in that the first tilting mirror 19 is tilted about the first tilting axis 27 by the actuator 25. The target position 9 of the laser beam 7 on the skin 11 is displaceable parallel to a Y-direction, which also lies in the contact surface 23 and is perpendicular to the X-direction, in that the second tilting mirror 21 is tilted about the second tilting axis 31 by the actuator 29.

As Fig. 1 further shows, the hair-removing device 1 comprises a separate illumination member 35 by means of which a portion of the skin 11 under treatment present below the opening 33 is illuminated during operation. The illumination member 35 may be a simple lamp. A light beam 37 supplied by the illumination member 35 during operation falls through a transparent plate 39, which also transmits the laser beam 7, onto said portion of the skin 11. The transparent plate 39 is positioned at an angle of approximately 45° with respect to

the contact surface 23 and is provided with a mirroring surface 41 at a side facing the opening 33. A light beam 43 reflected by said portion of the skin 11 is reflected by the mirroring surface 41 through an angle of approximately 90° and focused onto an image sensor 47, a CCD image sensor which is known per se in the embodiment shown, by means of a lens unit 45. The image sensor 47 is thus capable of detecting an image of said portion of the skin 11 present below the opening 33. The use of the illumination member 35 enables the image sensor 47 to detect a clear image of said portion of the skin 11 from the light of the illumination member 35 reflected by the skin 11, so that no reflected light from the laser beam 7 is necessary for detecting said image. This means that the laser source 3 can be fully switched off between the exposures of two consecutive target positions on the skin 11. In addition, the image sensor 47 may be provided with a filter, not shown in Fig. 1, for the reflected light of the laser beam 7, so that the image sensor 47 is protected against damage which may arise as a result of the reflected light of the laser beam 7 when the laser beam 7 is in the target position 9 with a high energy density.

As Fig. 1 shows, the image sensor 47 delivers to the control unit 17 an electrical signal u_s which corresponds to the image of the portion of the skin 11 present below the opening 33 detected by the image sensor 47, said signal u_s comprising, for example, a series of 8-bit grey tone values of the image sensor pixels. The detected image is shown diagrammatically in Fig. 3 and indicated with reference numeral 49. As Fig. 4 shows, the control unit 17 comprises a first processor 51, which scans the detected image 49 in a more or less regular manner, said processor 51 generating in succession a number of partial regions 53 of the image 49 as shown in Fig. 3, in particular a more or less regular sequence of partial regions 53 which lie approximately on a number of lines which lie one behind the other as seen in the Y-direction and which extend parallel to the X-direction. The first processor 51 supplies to a second processor 55 of the control unit 17 an electrical signal u_{sp} which corresponds in succession to the partial regions 53 of the image 49 successively generated by the first processor 51. The second processor 55 determines in each partial region 53 the position and the orientation on the skin 11 of the hair or hairs 13 present in the relevant partial region 53, and supplies an electrical signal u_{po} to a third processor 57 of the control unit 17 which corresponds in succession to the positions and orientations of the hairs 13 in the consecutive partial regions 53 of the image 49 as determined by the second processor 55. The third processor 57 determines in each partial region 53 one or several target positions for the laser beam 7 as a function of said position and orientation of the hair or hairs 13 in the relevant partial region 53 in a manner to be described in more detail below. The partial regions 53 have

dimensions which were determined on the basis of a previously determined average distance between the hairs 13 present on the skin 11 and a previously determined length of the hairs 13. In the embodiment shown, the dimensions of the partial regions 53 are such that the partial regions 53 comprise on average only a single hair 13 each. This can be achieved in practice if the user crops the hairs 13 by means of a trimmer prior to the treatment with the hair-removing device 1 to such a length that said previously determined length of the hairs 13 is smaller than said average distance between the hairs 13. Good results are achieved, for example, when the hairs 13 are cropped to a length of between 1 mm and 2 mm for an average distance between the hairs 13 of between 3 mm and 5 mm. It is noted that the first processor 51 generates the consecutive partial regions 53 of the image 49 preferably such that the hair 13 present in a partial region 53 lies approximately in a center of the relevant partial region 53. The sequence of consecutive partial regions 53 then obviously will not have the regularity shown in Fig. 3, but it is more or less regular, with the possibility, for example, of an interspacing being present between consecutive partial regions 53, or with consecutive partial regions 53 lying, for example, not exactly in one line. Since the partial regions 53 on average contain only a single hair 13 each, the position and the orientation of a hair 13 in a partial region 53 and the target positions of the laser beam 7 can be determined within a very short period of time by the second processor 55 of the control unit 17 and by the third processor 57 of the control unit 17, respectively, and a required calculation capacity of the second processor 55 and the third processor 57 can be strongly reduced. Preferably, the hair-removing device 1 further comprises an adjustment member, not shown in the Figures, by means of which the user of the hair-removing device 1 can set the dimensions of the partial regions 53. Said adjustment member for this purpose supplies to the first processor 51 an electrical signal u_A which corresponds to the dimensions set by the user. The user can thus adapt the dimensions of the partial regions 53 to the properties of the skin to be treated, in particular to the average distance between the hairs on the skin and the average length of the cropped hairs, so that the treatment result and the treatment time can be optimized by the individual user.

As Fig. 4 further shows, the third processor 57 supplies an electrical signal u_{TP} to a fourth processor 59 of the control unit 17, which signal corresponds consecutively to the target positions of the laser beam 7 determined by the third processor 57 in the consecutive partial regions 53. The fourth processor 59 determines a first output signal u_{M1} and a second output signal u_{M2} of the control unit 17, by means of which the control unit 17 controls the first tilting mirror 19 and the second tilting mirror 21 of the laser beam manipulator 5, respectively, as a function of the signal u_{TP} . The output signals u_{M1} and u_{M2} are determined by

the fourth processor 59 such that the tilting mirrors 19 and 21 are adjusted into positions which correspond to the target position of the laser beam 7 in the relevant partial region 53 which corresponds to the signal u_{TP} each time. The fourth processor 59 also supplies a third output signal u_L of the control unit 17 by means of which the control unit 17 controls the laser source 3. The fourth processor 59 delivers the output signal u_L at a predetermined moment after delivering the output signals u_{M1} and u_{M2} , said predetermined moment corresponding to a predetermined required adjustment time of the tilting mirrors 19 and 21. The fourth processor 59 supplies the output signal u_L with the predetermined pulse duration, so that the laser beam 7 is active in the relevant target position for the predetermined pulse duration.

The detected image 49 is regularly scanned by the control unit 17 in the manner described above in accordance with said sequence of consecutive partial regions 53, the laser beam manipulator 5 being adjusted by the control unit 17 into consecutive positions only which correspond to the target positions determined in the consecutive partial regions 53. This means that the laser beam manipulator 5 need be adjusted into a limited number of consecutive positions only, so that a particularly short treatment time is obtained by means of the hair-removing device 1. The laser beam manipulator 5, however, is adjusted in a comparatively irregular manner during this, so that comparatively high requirements are imposed on the adjustment accuracy of the laser beam manipulator 5 and on the adjustment time required for achieving a given adjustment accuracy. The fact that the target positions of the laser beam 7 are automatically determined by the control unit 17, and the fact that the laser source 3 is automatically activated by the control unit 17 after the laser beam manipulator 5 has been automatically adjusted into a correct, accurate position corresponding to a given target position by the control unit 17, render the hair-removing device 1 according to the invention particularly suitable for a safe use by inexperienced persons, so that the hair-removing device 1 is particularly suitable for the consumer market. The determination of the target positions of the laser beam 7 yet to be described in more detail below, the automatic adjustment of the laser beam manipulator 5, and the automatic activation of the laser source 3 take place in a comparatively short period of time, so that comparatively short treatment times are possible with the hair-removing device 1 according to the invention.

The target positions of the laser beam 7 are determined within a partial region 53 of the detected image 49 by the control unit 17 in the following manner. Fig. 5a diagrammatically shows a partial region 53 in which a hair 13 to be epilated is present. The second processor 55 of the control unit 17 determines from the signal u_{SP} a grey tone distribution for the relevant partial region 53, from which the position and the orientation of

the hair 13 on the skin 11 in the partial region 53 are determined. The second processor 55 also draws a distinction between a hair end 63 and a hair exit position 65 where the hair 13 issues from the skin 11. Said distinction is made by means of predetermined grey tone characteristics and shape characteristics of cropped hair ends and hair exit positions which are stored in the memory of the second processor 55. The third processor 57 of the control unit 17 subsequently determines from the position and orientation of the hair 13 and the exit position 65 thus determined a region 67 on the skin 11 below which the root 15 of the hair 13 will be present with a predetermined degree of probability. In the embodiment shown, it is assumed in the determination of said region 67 that the root 15 is present at a virtual rectilinear subcutaneous extension distance 69 of the hair 13, i.e. extending from the detected exit position 65, while it is further assumed that an angle α shown in Fig. 2 between the hair 13 and the surface of the skin 11 and a length L, also shown in Fig. 2, of a portion of the hair 13 present below the surface of the skin 11 lie between certain minimum and maximum values which were previously statistically determined. The region 67 thus determined is elongate and extends along a straight line segment 71 which lies on a virtual line which coincides substantially with a perpendicular projection of the hair 13 on the skin 11. The third processor 57 subsequently determines on the line segment 71 thus determined a number, for example three, of fixed target positions 9, 9', and 9'' for the laser beam 7, mutually overlapping by a small portion each time, and the third processor 57 supplies to the fourth processor 59 a number of consecutive signals u_{TP} which correspond to said target positions 9, 9', and 9''. As a result of this, the fourth processor 59 of the control unit 17 adjusts the laser beam manipulator 5 into a number of consecutive fixed positions which correspond to the target positions 9, 9', and 9'' of the laser beam 7 thus determined, the fourth processor 59 activating the laser source 3 for the predetermined pulse duration in each of the consecutive fixed positions of the laser beam manipulator 5.

Fig. 5b shows a partial region 53 of the detected image 49 in an alternative embodiment of the hair-removing device 1 according to the invention. In this alternative embodiment, the third processor 57 supplies to the fourth processor 59 a signal u_{TP} which corresponds to a displacement of the laser beam 7 with a predetermined velocity v over said straight line segment 71, so that the fourth processor 59 adjusts the laser beam manipulator 5 into a sequence of consecutive positions which correspond to said displacement of the laser beam 7. The fourth processor 59 of the control unit 17 in this alternative embodiment activates the laser source 3 at the start of said displacement and the fourth processor 59 switches off the laser source 3 at the end of said displacement. To obtain a result in this alternative

embodiment comparable to the result achieved by the embodiment shown in Fig. 5a, said predetermined velocity v of the laser beam 7 should be approximately equal to a quotient of the spot diameter of the laser beam 7 and the pulse duration used in Fig. 5a.

In the embodiment shown in Fig. 4, the control unit 17 further comprises a fifth processor 73 which determines a reflection spectrum of the portion of the skin 11 present below the opening 33 from the image 49 detected by the image sensor 47, i.e. from the signal u_S , and which compares this reflection spectrum with a predetermined reference spectrum which is stored in a memory of the fifth processor 73 and which contains information characteristic of at least one frequently occurring skin deviation. Fig. 6 shows an example of such a reflection spectrum, wherein the horizontal axis represent a measured grey tone G and the vertical axis a number of image sensor pixels N . The reflection spectrum shown comprises a first, comparatively great peak A with grey tones corresponding to a white skin, a second, comparatively small peak B with grey tones corresponding to dark hairs, and a third peak C with grey tones corresponding to said skin deviation. The fifth processor 73 determines from said comparison the positions on the skin 11 where said skin deviation occurs and supplies to a sixth processor 75 of the control unit 17 an electrical signal u_{BP} which corresponds to the positions on the skin 11 of said skin deviation thus determined. The sixth processor 75 compares the signal u_{TP} , which corresponds to a target position of the laser beam 7 determined by the third processor 57, with the positions on the skin 11 of said skin deviation thus determined, and supplies a signal u_{STOP} to the fourth processor 59 whenever the target position of the laser beam 7 coincides with one of the positions of said skin deviation on the skin 11. When the fourth processor 59 receives the signal u_{STOP} , the laser source 3 is not activated by the fourth processor 59. The use of the fifth processor 73 and the sixth processor 75 prevents the laser beam 7 from being active in positions on the skin 11 where said skin deviation is present. Examples of this are moles or other pigment spots. Such skin deviations have a comparatively high absorption power for the light of the laser beam 7 used, so that injuries may arise in the case of contact of these skin deviations with the light of the laser beam 7. The use of the fifth processor 73 and the sixth processor 75 provides an automatic protection against such injuries.

In the embodiment shown in Fig. 4, the fourth processor 59 determines the output signals u_{M1} and u_{M2} in accordance with a predetermined mathematical relation between the output signals u_{M1} , u_{M2} and the desired target position 9 of the laser beam 7 as determined by the third processor 57. Said mathematical relation is, for example, a linear function or a function of a higher degree comprising a number of coefficients. As a result of temperature

fluctuations or other factors, deviations of the target position 9 resulting from a predetermined value of the output signals u_{M1} , u_{M2} may arise. Such deviations can lead to a reduced efficiency of the hair-removing device 1 and to skin irritations or damages. To reduce or avoid such deviations and provide a very accurate positioning of the laser beam 7 on the skin 11 by the mirrors 19, 21, the control unit 17 further comprises a calibration member 81 for calibrating said predetermined mathematical relation on the basis of a measured relation between the output signals u_{M1} , u_{M2} and an actual position of the laser beam 7 on the skin 11. Said calibration, for example, constitutes a re-calculation of said coefficients of the predetermined mathematical relation on the basis of the measured relation between the output signals u_{M1} , u_{M2} and the actual position of the laser beam 7 on the skin 11, and is carried out by the control unit 17, for example, each time the hair-removing device 1 is started or each time after a predetermined time interval. To carry out said calibration, the mirrors 19, 21 are consecutively positioned in a predetermined number of calibration positions. For this purpose, the fourth processor 59 consecutively supplies a predetermined number of output signals u_{M1} , u_{M2} having predetermined values. In each calibration position of the mirrors 19, 21, the actual position of the laser beam 7 on the skin 11 is determined by means of a seventh processor 83 of the control unit 17, which determines said actual position from the image detected by the image sensor 47. For this purpose, as shown in Fig. 4, the seventh processor 83 receives the signal u_S supplied by the image sensor 47, and supplies a signal u_{AP} corresponding to the actual position of the laser beam 7 on the skin 11 to the calibration member 81. After the determination of the actual position of the laser beam 7 in each calibration position of the mirrors 19, 21, the calibration member 81 supplies a signal u_{CAL} corresponding to the re-calculated coefficients of the predetermined mathematical relation to the fourth processor 59. During said calibration process, the fourth processor 59 activates the laser source 3 at a comparatively low energy density via a suitable value of the signal u_L . Said energy density is as low as possible, but such that the spot of the laser beam 7 on the skin 11 is still sufficiently bright to be detected by the image sensor 47. In this manner, skin irritation or damage are prevented during the calibration process, and the energy consumption of the laser source 3 is limited. It is noted, that the invention also comprises embodiments, in which the actual position of the laser beam 7 on the skin 11 is determined in a similar manner from the image detected by the image sensor 47, but in which the laser beam manipulator 5 is corrected in a different manner. The control unit 17 may, for example, alternatively be provided with a feed back control circuit comprising a comparator, which compares the actual position of the laser beam with the desired target position and supplies an error signal, and a PID regulator, which

determines the output signals u_{M1} and u_{M2} on the basis of said error signal in such a manner that the measured actual position equals the desired target position. The invention also comprises embodiments, in which the actual position of the laser beam on the skin is not determined by means of the image sensor, but by means of a separate sensor means such as, for example, sensors which directly measure the angular positions of the mirrors 19, 21.

As Fig. 1 shows, the hair-removing device 1 according to the invention further comprises a handle 81 by means of which the user can place the hair-removing device 1 on the skin 11 to be treated and can displace it over the skin 11. As was described above, the portion of the skin 11 present below the opening 33 only is treated. After the treatment of said portion of the skin 11, the user should displace the hair-removing device 1 into a next position on the skin 11. The hair-removing device 1 may be provided, for example, with an acoustic source which is triggered by the control unit 17 and which produces an acoustic signal the moment the treatment of the portion of the skin 11 present below the opening 33 has been completed. The hair-removing device 1 may alternatively be provided, for example, with electrical drive means controlled by the control unit 17 for the automatic displacement of the hair-removing device 1 over the skin 11 to be treated, instead of with such an acoustic source.

Fig. 7 shows a control unit 17' of a further embodiment of a hair-removing device 1' according to the invention. Apart from the control device 17', the hair-removing device 1' has a composition comparable to that of the hair-removing device 1 according to the invention shown in Fig. 1. Components of the hair-removing device 1' corresponding to components of the hair-removing device 1 described above have been given the same reference numerals in Fig. 7, and the description below will deal exclusively with the differences between the control units 17 and 17' and the resulting differences in operation between the hair-removing devices 1 and 1'.

As Fig. 7 shows, the control unit 17' likewise comprises a first processor 51, a second processor 55, a third processor 57, a fourth processor 59, a fifth processor 73, and a sixth processor 75. The control unit 17' comprises furthermore a seventh processor 77 which determines the first output signal u_{M1} and the second output signal u_{M2} by means of which the control unit 17' controls the first tilting mirror 19 and the second tilting mirror 21 of the laser beam manipulator 5, respectively. The control unit 17' likewise comprises a calibration member 81 and an eighth processor 83, which correspond with the calibration member 81 and the seventh processor 83 of the control unit 17 and which cooperate with the image sensor 47 and the seventh processor 77 in a manner similar to the manner in which the calibration member 81 and the seventh processor 83 of the control unit 17 correspond with the image

sensor 47 and the fourth processor 59. The seventh processor 77 determines the output signals u_{M1} and u_{M2} such that the tilting mirrors 19 and 21 are adjustable into a sequence of consecutive positions which correspond to a regular sequence of virtual positions of the laser beam 7 on the portion of the skin 11 below the opening 33, in particular with a displacement of the virtual position of the laser beam 7 with a predetermined velocity v' in accordance with a number of lines extending parallel to the X-direction and following one another as seen in the Y-direction. As Fig. 7 shows, the seventh processor 77 here supplies to the first processor 51 an electrical signal u_{IP} which corresponds to the instantaneous virtual position IP of the laser beam 7. The first processor 51 generates from the signals u_S and u_{IP} a partial region 53' of the image 49 which is diagrammatically shown in Fig. 8 and which has dimensions determined by a previously determined average distance between the hairs 13 present on the skin 11 and a previously determined length of the hairs 13. The dimensions of the partial region 53' can be set by the user by means of an adjustment member which is not shown and which supplies to the first processor 51 an electrical signal u_A which corresponds to the dimensions of the partial region 53' as set by the user. The first processor 51 generates the partial region 53' such that a reference position R in the partial region 53' shown in Fig. 8, in particular a central position of the partial region 53', corresponds continually to the instantaneous virtual position IP of the laser beam 7. The partial region 53' thus follows the rectilinear displacement of the instantaneous virtual position IP of the laser beam 7 over the image 49. Fig. 8 also shows a number of lines 79 along which the instantaneous virtual position IP of the laser beam 7 is displaced over the image 49. The first processor 51 supplies to the second processor 55 an electrical signal u_{SP} which corresponds to the partial region 53', and the second processor 55 determines from the signal u_{SP} the position and the orientation in the partial region 53' of the hair 13 present in the partial region 53'. The second processor 55 supplies to the third processor 57 an electrical signal u_{PO} which corresponds to the position and the orientation of the hair 13 in the partial region 53' as determined by the second processor 55, and the third processor 57 determines from the signal u_{PO} the target positions 9, 9', and 9'' of the laser beam 7 in the partial region 53'. The third processor 57 supplies to the fourth processor 59 an electrical signal u_{TP} which corresponds to the target positions 9, 9', and 9'' of the laser beam 7 as determined by the third processor 57. The fourth processor 59 compares the instantaneous virtual position IP of the laser beam 7 with the target positions 9, 9', and 9'' of the laser beam 7 and activates the laser source 3 by means of the output signal u_L during the previously determined pulse duration whenever the instantaneous virtual position IP of the laser beam 7 corresponds to one of the target positions 9, 9', or 9'' of the laser beam 7 in

the partial region 53'. The fifth processor 73 and the sixth processor 75 in the control unit 17' have functions comparable to those of the fifth processor 73 and the sixth processor 75 in the control unit 17.

5 An advantage of the hair-removing device 1' with the control unit 17' is that the laser beam manipulator 5 is continually adjusted by the control unit 17' in a regular manner, so that the laser beam manipulator 5 need not have an exceptionally high adjustment accuracy and an exceptionally short adjustment time. The portion of the skin 11 present below the opening 33 is scanned by the laser beam manipulator 5 in a regular manner, and the partial region 53' of the image 49 generated by the control unit 17' follows the virtual position IP of
10 the laser beam 7 on said portion of the skin 11, the target positions 9, 9', and 9'' of the laser beam 7 changing continually with respect to the reference point R of the partial region 53'. Good results are obtained in this further embodiment of the hair-removing device 1' when an interspacing is present between the consecutive lines 79 in the image 49 which is equal to or is preferably smaller than the spot diameter of the laser beam 7. However, scanning of all lines
15 79 present in the image 49 by the laser beam manipulator 5 takes longer than the direct displacement of the laser beam manipulator 5 into the consecutive target positions in the image 49 as in the hair-removing device 1, so that the hair-removing device 1' will have a longer treatment time than the hair-removing device 1 in most cases.

The hair-removing devices 1 and 1' described above are epilation devices by
20 means of which hairs 13 are removed from the skin 11 for a comparatively long period or even permanently. A yet further embodiment of a hair-removing device 1'' according to the invention operates as a shaver. The hair-removing device 1'' has a construction which is largely identical to the construction of the hair-removing device 1 shown in Fig. 1. The hair-removing device 1'' differs from the hair-removing device 1 in that the hair-removing device
25 1'' determines the target position 9 of the laser beam 7 on the skin 11 in a different manner. Fig. 9 diagrammatically shows a partial region 53'' of the image 49 of the skin 11 under treatment which is detected by means of the image sensor 47 of the hair-removing device 1''. The third processor 57 of the control unit 17 of the hair-removing device 1'' determines the target position 9 of the laser beam 7 such that this target position 9 lies on the hair 13 to be
30 removed adjacent the exit position 65 of the hair 13 determined by the second processor 55. The hair 13 is thus burnt through by the laser beam 7 adjacent the exit position 65. The control unit 17 of the hair-removing device 1'' can be so programmed that the target position 7 lies flush with or even below the surface of the skin 11, so that a very smooth shaving result is achieved with the hair-removing device 1'', which is maintained for a comparatively long

period. The hair-removing device 1" may be further provided with an adjustment member by means of which the user can adjust the location of the target position 9 relative to the surface of the skin 11, thus adjusting a desired smoothness. It was found that the burning-through of hairs 13 by means of the laser beam 7 is possible at an energy density of the laser beam 7 which is considerably smaller than the energy density necessary for the epilation of the hairs 13 as described above. The hair-removing device 1" may thus be provided with a comparatively small and inexpensive laser diode with a power of, for example, between 100 mW and 500 mW.

It is noted that the invention also covers a hair-removing device in which the epilation function and the shaving function as described above are combined, in which case the user can select the desired mode of operation, for example by means of an adjustment member. Preferably, the energy density of the laser source is also controllable by means of the control unit of such a hair-removing device, so that the energy density of the laser source can be adapted to the desired mode of operation of the hair-removing device. If the hair-removing device has an epilation function or has been set as an epilation device by the user, the hair-removing device may also be provided, for example, with an automatic shaving function. If the hair-removing device has exclusively an epilation function, in which case exclusively the roots 15 of the hairs 13 are destroyed, the hairs 13 will not disappear from the skin 11 until after some time, so that the desired result is not achieved immediately. If the epilation function of the hair-removing device is automatically combined with a shaving function, it is not only the roots 15 of the hairs 13 which are destroyed, but the hairs 13 are also burnt through adjacent the surface of the skin 11, so that the hairs 13 are immediately removed from the skin 11 and the desired result is achieved instantaneously.

It is further noted that a hair-removing device according to the invention may be provided with a different type of laser beam manipulator instead of the laser beam manipulator 5 having the two tilting mirrors 19 and 21 as described above. Thus, for example, the two tilting mirrors 19 and 21 may be replaced by a single tilting mirror which is tiltable about two mutually perpendicular tilting axes. Instead of a laser beam manipulator with one or more than one tilting mirror, for example, a laser beam manipulator may alternatively be used which is provided with an object holder which is displaceable in two mutually perpendicular directions, in which case the laser source and the image sensor are fastened to said object holder in fixed positions.

It is further noted that the invention also covers embodiments of the hair-removing device in which a type of image sensor is used different from the image sensor 47

with CCD as described above. An example of such an image sensor is a CMOS image sensor. Such a CMOS image sensor may be provided with a RAM memory, so that part of the control unit or even the entire control unit of the hair-removing device can be integrated with the CMOS image sensor. The construction and manufacture of the hair-removing device are
5 considerably simplified in this manner.

In the embodiments of the hair-removing device according to the invention described above, the control unit determines the target position of the laser beam each time in a partial region of the image of the skin detected by means of the image sensor. It is noted that the invention also relates to embodiments in which the control unit determines the target
10 positions of the laser beam once and for all in the entire image of the skin detected by the image sensor. Such embodiments, however, require a control unit with a comparatively great calculation capacity and memory capacity.

It is finally noted that the invention also relates to embodiments of the hair-removing device in which the positions of the hairs on the skin under treatment are not
15 detected by means of reflected light of a separate illumination member, such as the illumination member 35 described above, but in which the positions of the hairs are detected by means of reflected light from the laser beam. The skin to be treated is scanned by means of the laser beam in such embodiments, during which the laser beam has a comparatively low energy density, which energy density of the laser beam is temporarily raised in the target
20 position. The reflected light of the laser beam may be detected in such embodiments, for example, by means of a simple photodetector which detects only the intensity of the reflected light of the laser beam. The expression "image sensor for detecting an image of at least a portion of the skin" in the claims therefore also relates to such a comparatively simple photodetector. Such a method of detection may be used in a comparatively simple manner in
25 the hair-removing device 1' described with reference to Fig. 7, but it may also be used in, for example, a hair-removing device provided with a laser beam manipulator with a displaceable object holder as described above.

CLAIMS:

1. A hair-removing device provided with a laser source, an adjustable laser beam manipulator for positioning a laser beam supplied by the laser source during operation in a target position on a skin to be treated, and an image sensor for detecting an image of at least a portion of the skin, characterized in that the laser source is controllable by means of an
5 electrical control unit, which control unit during operation determines the target position of the laser beam as a function of a position and/or orientation on the skin of a hair to be removed as determined from the image by the control unit, and which control unit activates the laser source the moment the laser beam manipulator is in a position which corresponds to the target position of the laser beam.

10 2. A hair-removing device as claimed in claim 1, characterized in that the control unit determines the target position of the laser beam in a partial region of the image having dimensions which are determined by a previously determined average distance between hairs present on the skin and a previously determined length of the hairs.

15 3. A hair-removing device as claimed in claim 2, characterized in that the dimensions of the partial region of the image are adjustable.

20 4. A hair-removing device as claimed in claim 2, characterized in that the laser beam manipulator is adjustable by means of the control unit into a sequence of consecutive positions which correspond to a regular sequence of virtual positions of the laser beam on said portion of the skin, a reference position in the partial region of the image corresponding to the instantaneous virtual position of the laser beam, and the control unit activating the laser source when the reference position corresponds to the target position of the laser beam.

25 5. A hair-removing device as claimed in claim 2, characterized in that the control unit determines the target position of the laser beam in a regular sequence of consecutive partial regions of the image, the laser beam manipulator being adjustable by means of the

control unit in each of said partial regions into a position which corresponds to the target position of the laser beam in the relevant partial region.

6. A hair-removing device as claimed in claim 1, characterized in that the control unit determines from the position and orientation on the skin of the hair to be removed, as determined from the image, a region on the skin below which a root of the hair will be present with a predetermined degree of probability, the control unit determining at least one target position on the skin in said region.

7. A hair-removing device as claimed in claims 5 and 6, characterized in that the laser beam manipulator is adjustable by means of the control unit into a sequence of consecutive positions which correspond to a displacement of the laser beam over a rectilinear path on the skin with a predetermined velocity, said rectilinear path lying on a virtual straight line which coincides substantially with a perpendicular projection of the hair to be removed on the skin, the control unit activating the laser source at the start of said displacement.

8. A hair-removing device as claimed in claims 5 and 6, characterized in that the laser beam manipulator is adjustable by means of the control unit into a number of consecutive fixed positions corresponding to a number of fixed target positions of the laser beam on a rectilinear path on the skin, which rectilinear path lies on a virtual straight line which coincides substantially with a perpendicular projection of the hair to be removed on the skin, the control unit activating the laser source in each of said fixed positions of the laser beam manipulator during a predetermined time.

9. A hair-removing device as claimed in claim 1, characterized in that the control unit determines an exit position on the hair, where the hair issues from the skin, from the position and orientation on the skin of the hair to be removed as determined from the image, the control unit equalizing the target position of the laser beam with a position on the hair adjacent said exit position.

10. A hair-removing device as claimed in claim 1, characterized in that the hair-removing device comprises a separate illumination member for illuminating at least the portion of the skin which is to be detected by the image sensor.

11. A hair-removing device as claimed in claim 1, characterized in that the control unit determines from the image a reflection spectrum of the skin portion detected by the image sensor, the control unit comparing the reflection spectrum with a predetermined reference spectrum of at least one frequently occurring skin deviation, while the control unit determines
5 from said comparison positions on the skin in which said skin deviation is present and does not activate the laser source in said positions on the skin.

12. A hair-removing device as claimed in claim 1, characterized in that the control unit comprises means for determining an actual position of the laser beam on the skin from the
10 image detected by the image sensor.

13. A hair-removing device as claimed in claim 12, characterized in that the laser beam manipulator is adjustable by means of the control unit via an output signal of the control unit in accordance with a predetermined mathematical relation between said output signal and
15 the target position, the control unit comprising a calibration member for calibrating said predetermined mathematical relation on the basis of a measured relation between said output signal and the actual position of the laser beam on the skin.

14. A hair-removing device as claimed in claim 12, characterized in that, for
20 determining the actual position of the laser beam on the skin, the control unit activates the laser source at a comparatively low energy density.

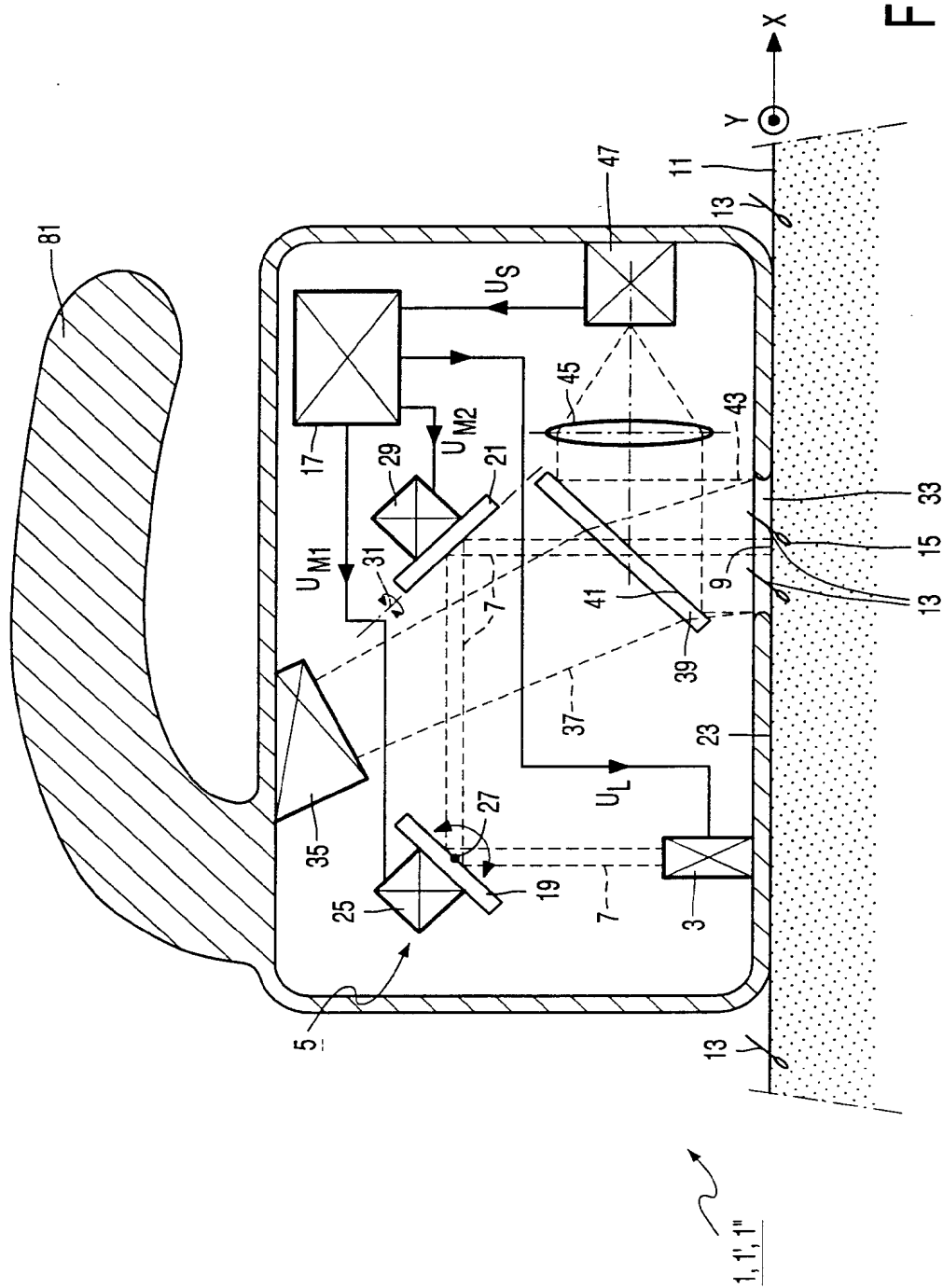


FIG. 1

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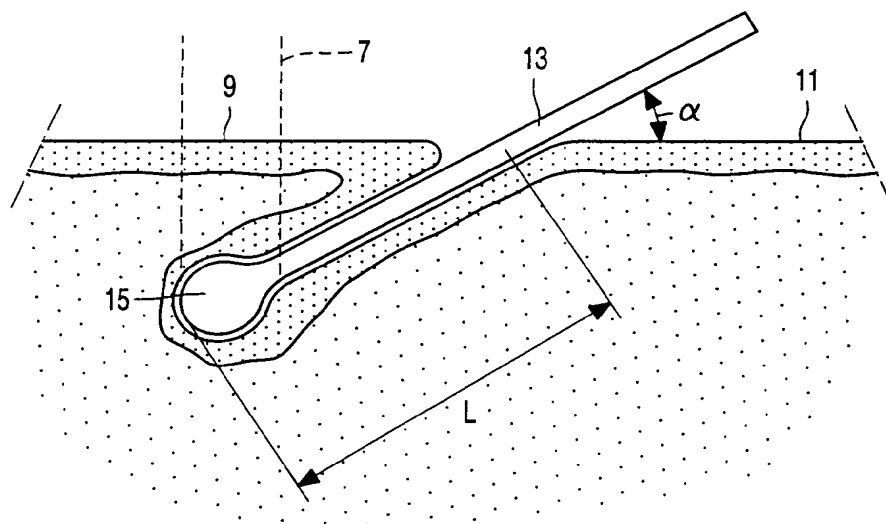


FIG. 2

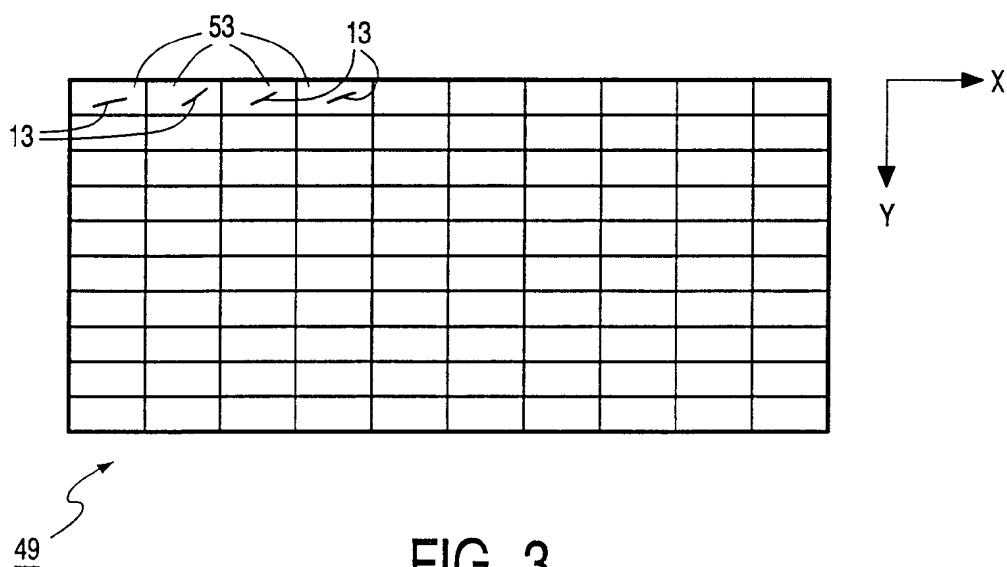


FIG. 3

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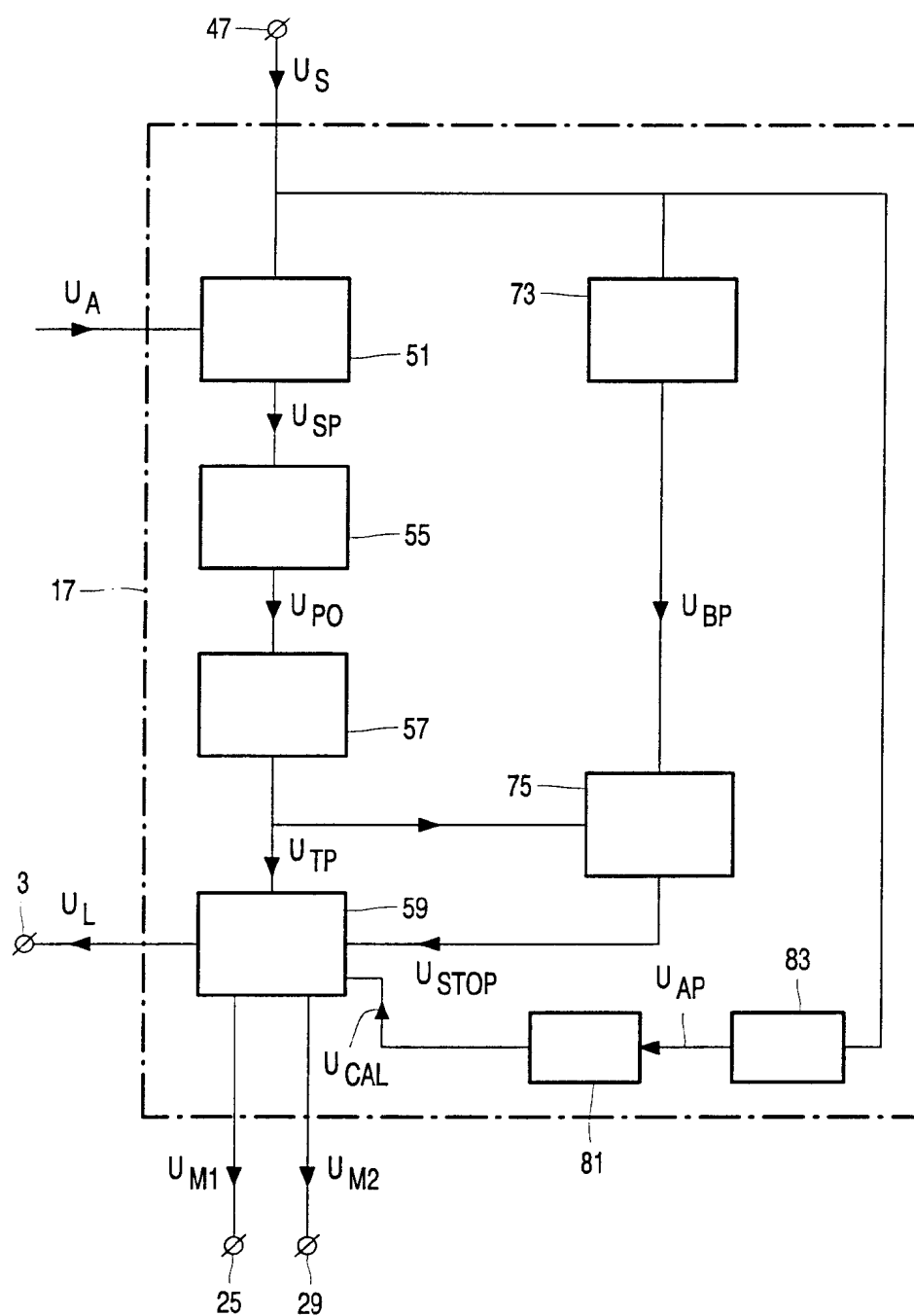


FIG. 4

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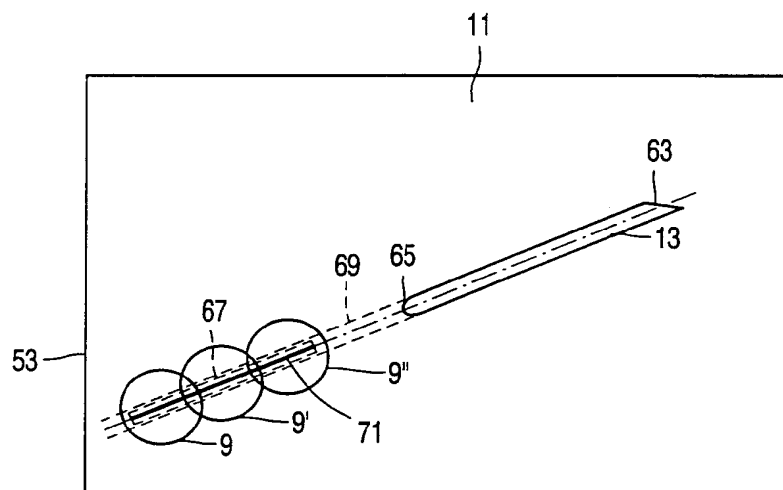


FIG. 5A

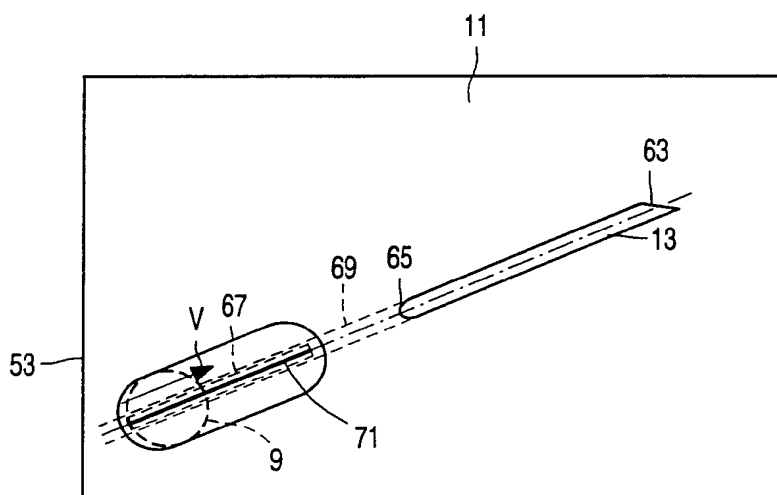


FIG. 5B

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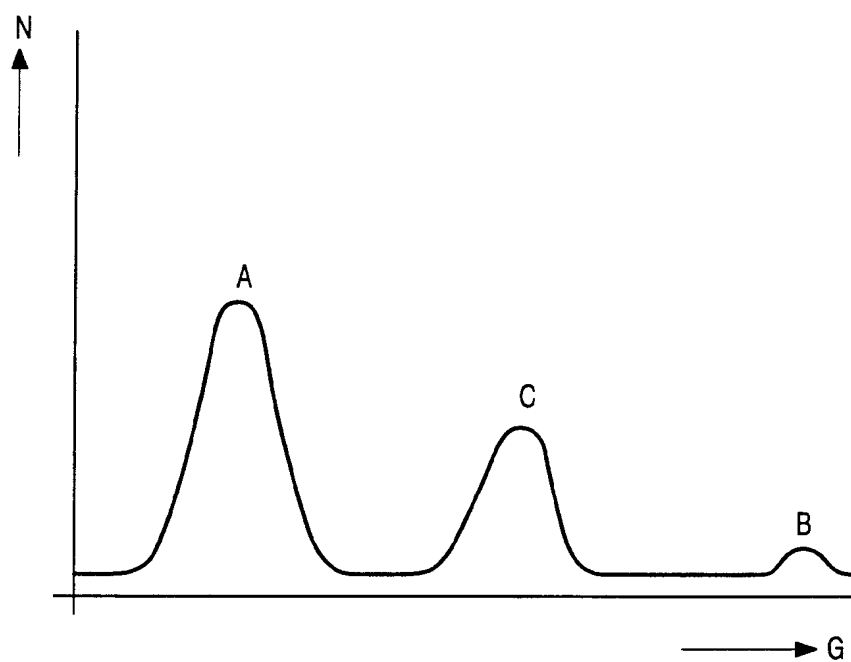


FIG. 6

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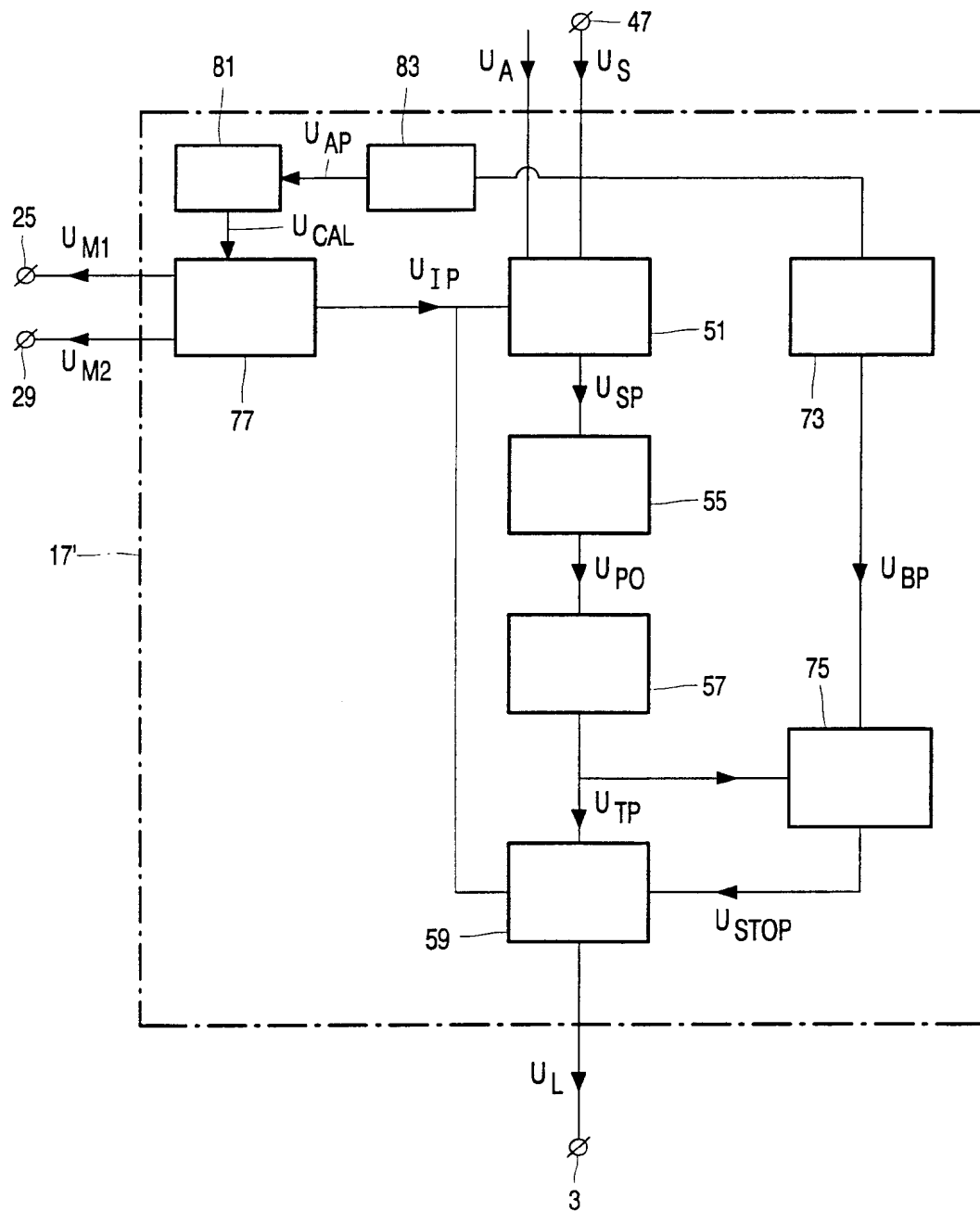
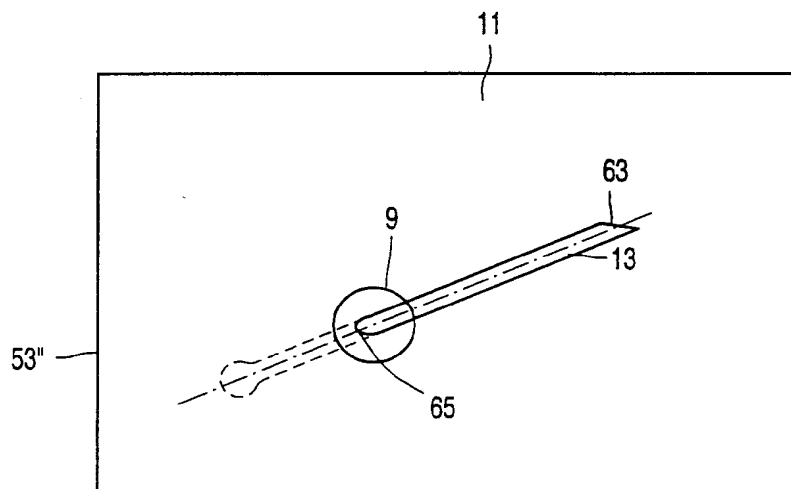
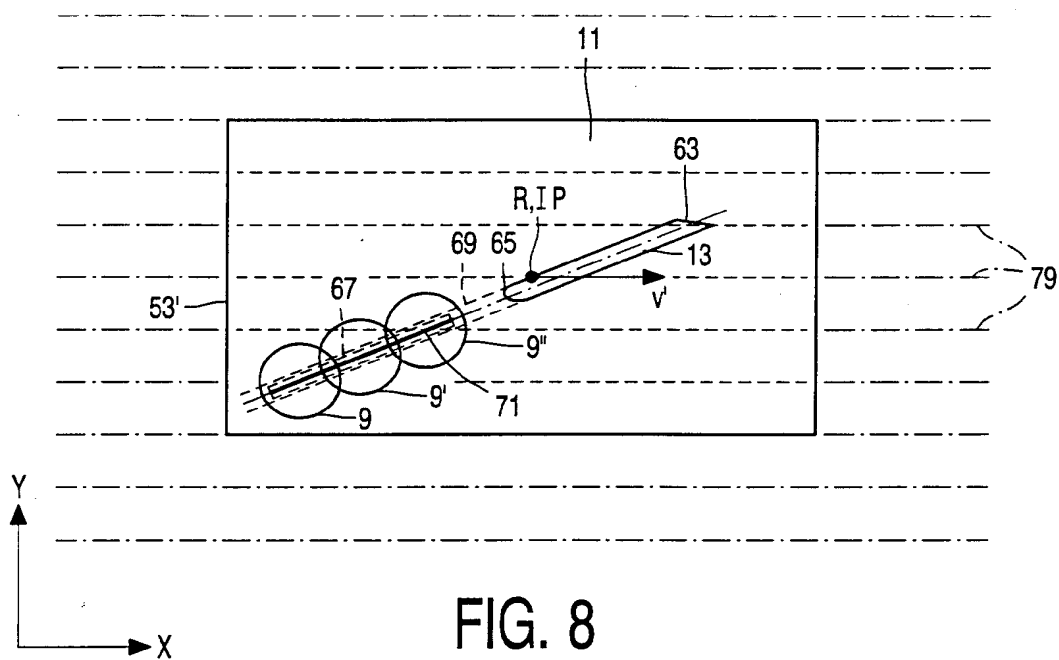


FIG. 7

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INTERNATIONAL SEARCH REPORT

International Application No

PCT/EP 00/02871

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 A61B18/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 99 11324 A (BALLE PETERSEN OLAV ; ASAH BJARNE (DK); ASAH MEDICO A S (DK); DOLLE) 11 March 1999 (1999-03-11) page 3, line 12 - line 17 page 10, line 2 - line 9 page 12, line 7 - line 15 page 14, line 8 - line 10 page 19, line 33 - page 20, line 13	1, 10, 11
Y	---	12
Y	EP 0 880 941 A (NIDEK KK) 2 December 1998 (1998-12-02) column 7, line 7 - column 8, line 45 column 11, line 56 - column 12, line 18 ---	12
	-/--	

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

11 August 2000

Date of mailing of the international search report

21/08/2000

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Authorized officer

Petter, E

INTERNATIONAL SEARCH REPORT

Int lional Application No

PCT/EP 00/02871

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 860 967 A (EASTMAN JAY M ET AL) 19 January 1999 (1999-01-19) column 4, line 9 - line 19 column 4, line 53 - line 65 ---	1
A	US 5 836 872 A (TEARNEY GUILLERMO J ET AL) 17 November 1998 (1998-11-17) column 2, line 8 - line 43 column 5, line 24 - line 67 column 10, line 25 - line 38 column 18, line 40 -column 20, line 11 ---	1
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INTERNATIONAL SEARCH REPORT

information on patent family members

International Application No

PCT/EP 00/02871

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DE 3837248 A	03-05-1990	NONE	

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
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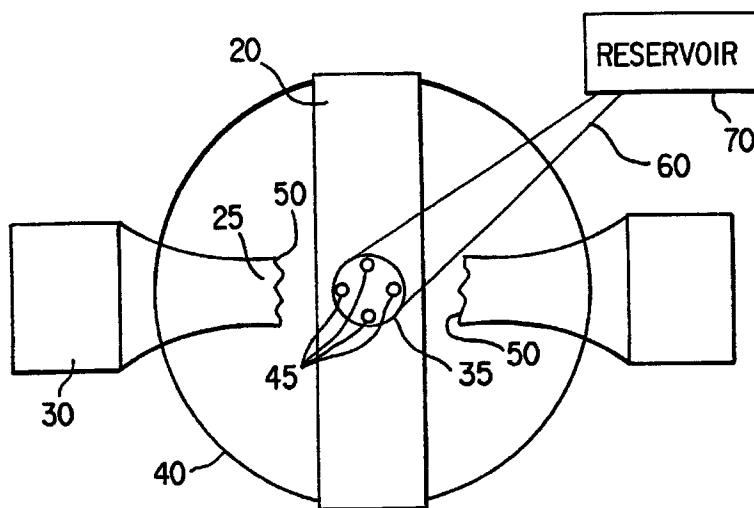
PCT

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60/138,193 9 June 1999 (09.06.1999) US
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- (81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.
- (84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).
- Published:**
— With international search report.
— Before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments.

[Continued on next page]

(54) Title: SELF-REMOVING ENERGY ABSORBING STRUCTURE FOR THERMAL TISSUE ABLATION



(57) Abstract: A device to facilitate ablation of tissue, such as for forming one or more openings in the tissue for transdermal monitoring and/or delivery applications. The device comprises: (a) a support layer having at least one aperture therein, and (b) at least one energy absorbent film layer disposed over the at least one aperture in the support layer for making substantial contact with tissue through the aperture. The at least one energy absorbent film layer is under a tension force and absorbs energy focused thereon to thermally ablate the tissue. After ablation, the film layer breaks apart allowing access to the ablated tissue beneath it.



WO 00/74583 A1



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**SELF-REMOVING ENERGY ABSORBING STRUCTURE FOR
THERMAL TISSUE ABLATION**

CROSS REFERENCE TO RELATED APPLICATION

5

This application claims priority to U.S. Provisional Application Serial No. 60/138,193 filed June 9, 1999 which is incorporated by reference in its entirety.

FIELD OF THE INVENTION

10

This invention relates to the field of tissue ablation for the formation of openings in the tissue. In particular, this invention relates to self-removing energy absorbing structures for achieving thermal tissue ablation.

15

BACKGROUND OF THE INVENTION

20

The flux of a drug or analyte across a biological tissue can be increased by changing the diffusion coefficient or the gradient for diffusion. Commonly, the flux is enhanced by increasing the permeability of the skin, such as by chemical penetration enhancers, iontophoresis, and poration techniques.

Thermal tissue ablation for forming openings in tissue is disclosed in commonly assigned U.S. Patent No. 5,885,211 to Eppstein, et al. There is room for improving the thermal tissue ablation process.

25

SUMMARY OF THE INVENTION

The present invention is directed to a device to facilitate ablation of tissue, such as for forming one or more openings in the tissue for transdermal monitoring and/or delivery applications. The device comprises: (a) a support layer having at

least one aperture therein, and (b) at least one energy absorbent film layer disposed over at least one aperture in the support layer for making substantial contact with tissue through the aperture. The at least one energy absorbent film layer is under a tension force over or across the aperture and absorbs energy focused thereon to thermally ablate the tissue. After ablation, and because it is under tension, the film layer breaks apart allowing access to the ablated tissue beneath it.

The present invention is further directed at a method for forming openings in a tissue comprising the steps of: (a) positioning a support layer having an aperture therein on a tissue; (b) positioning an energy absorbent film layer over the aperture to make substantial contact with the tissue through the aperture; and (c) focusing energy onto the energy absorbent film layer to conduct heat to the tissue thereby ablating the tissue.

The above and other advantages of the present invention will become more readily apparent when reference is made to the following description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a perspective view of one embodiment of a portion of the device of the present invention.

Figure 2 is cross-sectional view taken through line A-A of Figure 1 and illustrating the relationship of the energy absorbent film to the tissue when suction is applied to the device.

Figure 3 is a top view of one embodiment of a portion of the device showing the energy absorbent film before it has been affected by energy.

Figure 4 is a top view of one embodiment of a portion of the device showing the energy absorbing layer after it has been affected by energy.

Figure 5 is a top view of one embodiment of a portion of the device used as part of a transdermal delivery system.

Figure 6 is a top view of one embodiment of a portion of the device used as part of a monitoring system.

5

DETAILED DESCRIPTION OF THE INVENTION

The present invention may be understood more readily by reference to the following detailed description of various embodiments of the invention and the
10 Figures.

Before the present articles and methods are disclosed and described, it is to be understood that the terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting. It must be noted that, as used in the specification and the appended claims, the singular forms "a,"
15 "an" and "the" include plural referents unless the context clearly dictates otherwise.

Ranges may be expressed herein as from "about" or "approximately" one particular value and/or to "about" or "approximately" another particular value. When such a range is expressed, another embodiment comprises from the one particular value and/or to the other particular value. Similarly, when values are
20 expressed as approximations, by use of the antecedent "about," it will be understood that the particular value forms another embodiment.

As used herein, "opening" means any size hole, aperture or pore of any depth, that is capable of substance transport therethrough. Inclusive in this term is at least one opening in the tissue sized no larger than about 1000 μm in diameter
25 called a micropore.

Throughout this application, where publications are referenced, the disclosures of these publications in their entireties are hereby incorporated by

reference into this application in order to more fully describe the state of the art to which this invention pertains.

Referring first to **Figures 1-3**, one embodiment of a portion of the present invention **100** is shown. The device **100** includes at least a support layer **7** and an energy absorbent film layer **25**. Depending on the application of the device **100**, it also includes an optional assay reagent pad **20**. The energy absorbent film layer **25** is stretched or otherwise placed under tension across a hole or aperture **40** in the support layer **7**. At least one hole or aperture **35** is provided in the assay reagent pad **20** above the hole **40** and the energy absorbent film **25**. The hole(s) **35** may be any shape or size to provide a suitable site for tissue ablation.

In one embodiment of the invention, the energy absorbent film layer **25** of **Figure 1** is held in place and under tension across the aperture **40** by at least one tension member **30**. This tension member(s) **30** may be constructed of any suitable material in any shape to create a tension force across the film **25**. In one form, at least one tension member **30** is provided at one end of the energy absorbent film layer **25** and the other end is fixed to the support layer **7** by other suitable means, such as by glue or spot weld attachment. In another form, at least one tension member **30** is provided at both ends of the energy absorbent film layer **25** to hold it under tension across the aperture **40**. Examples of materials suitable for the tension member(s) **30** include elastic, rubber, metal springs, or plastic springs or the like.

In another embodiment of the invention, tension members **30** are not needed and the film **25** is anchored directly to the support layer **7**. Such anchoring may be performed by any suitable means including adhesive bonding, electromagnetic bonding, hot plate welding, induction bonding, insert bonding, radio-frequency sealing, spot welding, thermostacking, chemical bonding, thermo bonding, vibration welding or ultrasonic welding. Examples of film **25** suitable for

such use without tension members include pre-stretched mylar, rubber, silicone, polycarbonate, polyurethane, polyvinyl chloride, or polypropylene film.

The support layer **7** serves to support the film **25** across the aperture **40**. As such, suitable materials for the support layer **7** include polyester, ceramic, polycarbonate (PC), polyvinylchloride (PVC), and mixtures thereof. This support layer can be of any suitable thickness to maintain structural support for the film **25**.

The optional assay reagent pad **20** serves to detect the presence of a substance in the fluid. For example, the assay reagent pad **20** may be useful in detecting the presence of an analyte (such as glucose) in blood or interstitial fluid. The assay reagent pad **20** may be constructed of any suitable material, with as many layers or materials as necessary for detecting the presence of a substance in a fluid. Elements of the assay reagent pad include electrodes, one or more enzymes, and one or more indicators as is well known in the electrochemical biosensor art. The assay reagent pad **20** alternatively may be a type that is optically interrogated to determine a measurement of an analyte. The assay reagent pad **20** may be attached to the film **25** or may be placed proximate to the film **25** such that the pad **20** is capable of fluid communication with the film **25**.

The energy absorbent film layer **25** includes a layer of material that absorbs energy and heats up. As the energy absorbent film layer **25** is heated by a beam or field **10** of energy, the film **25** transfers heat to the tissue by conduction, thereby ablating the tissue. One use of ablating the tissue is to form one or more openings in the tissue for transdermal monitoring or delivery applications. Thermal tissue ablation for forming openings is described more fully in U.S. Patent No. 5,885,211.

Any suitable energy may be used for the beam of energy **10** to heat the energy absorbent film **25**. In one embodiment, the beam of energy **10** is a beam of optical energy, which may for example be provided by a laser diode. In another embodiment, the energy **10** is comprised of electromagnetic energy, laser, gamma radiation, and/or beta radiation, etc.

The types of energy absorbing substances that are suitable for the film **25** include those disclosed in commonly assigned U.S. Patent No. 5,885,211, and in commonly assigned PCT/0599/04929, filed March 5, 1999, both of which are incorporated herein by reference in their entireties. Copper pythalocyanine doped
5 film is an example of a suitable film **25** material. Alternatively, a clear film **25** with an absorbent adhesive layer can be used whereby the adhesive provides a positive attachment to the targeted tissue, and a thermal conduction path to the tissue. Once the aperture **40** is formed and the film **25** is retracted from the opening, the adhesive also serves to help stretch the aperture **40** and the attached
10 tissues beneath the surface, increasing the flux rate to facilitate extraction or delivery of substances via the aperture **40**.

The operation of the device will now be described with reference to **Figures 1-4**. As shown in **Figure 1**, a vacuum or suction **15** is applied (by a vacuum source not shown) to a region **27** of the device **100** so as to pull the tissue
15 **5** up to contact the film **25** through the aperture **40** of the support layer **7** (**Figure 2**). The film **25** flexes to provide good physical contact with the underlying tissue **5** which is desirable to achieve efficient transfer of heat to the tissue when the energy absorbent film layer **25** is heated.

The beam or field **10** of energy is then directed onto the energy absorbent
20 film **25**. In response, the film **25** heats up and the heat in the film is transferred by conduction to the tissue **5**, thereby ablating the tissue. As the film **25** absorbs the energy and transfers it to the tissue, eventually, because of the tension force, it breaks and separates across the aperture **40** as illustrated in **Figure 4**. The film **25** burns up as the thermal ablation process occurs and in so doing is weakened to be
25 overcome by the tension force. This self-removal or self-separating feature of the film **25** allows access to the ablated area of the tissue to facilitate fluid communication with the opening(s) **45** without any additional steps.

Figure 5 depicts the device **100** used in connection with a transdermal delivery system wherein at least one drug or agent is delivered to the tissue **5** via the opening(s) in the tissue **45**. A reservoir **70** containing the at least one drug or agent may be in fluid communication with the opening(s) in the tissue **45** via a
5 conduit **60**, such as tubing. Alternatively, the reservoir **70** may be integrally formed with the support layer **7** so that the at least one drug or agent can be delivered into the tissue **5** in a single step procedure with gravity or pressure forcing the drugs or agents into the tissue **5**.

Figure 6 shows the device **100** used in connection with a monitoring
10 system. The assay reagent pad **20** may be located on the device **100** and connected (wired or wirelessly) to a monitoring apparatus **200**. Alternatively, the assay reagent pad **20** may be located remotely in the monitoring apparatus **200** and coupled via fluid conduit **60** that carries the fluid.

Whether the assay reagent pad **20** is located remote or proximate to the
15 opening(s) in the tissue **45** depends on the specific application. Both embodiments are useful in discrete monitoring applications for analyzing fluid on a single use basis, as well as in continuous monitoring applications for continuously extracting and analyzing fluid over a longer term basis, such as several hours, days, etc. See, for example, International Application No. PCT/US99/16378, filed July 20, 1999,
20 entitled "System and Method for Continuous Analyte Monitoring".

It will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the scope or spirit of the invention. Other embodiments of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the
25 invention disclosed herein. It is intended that the specification and examples be considered as exemplary only, with the true scope and spirit of the invention being indicated by the following claims.

What is claimed is:

1. A device to facilitate thermal ablation of tissue, comprising:
 - (a) a support layer having at least one aperture therein; and
 - (b) at least one energy absorbent film layer disposed over the at least one aperture in the support layer for making substantial contact with tissue through the aperture, wherein the at least one energy absorbent film layer is under a tension force; and absorbs energy focused thereon to thermally ablate the tissue.
2. The device of claim 1, further comprising an assay pad disposed proximate the aperture in the support layer.
3. The device of claim 2, wherein the assay pad has at least one aperture aligned with the at least one aperture in the support layer.
4. The device of claim 1, wherein the energy absorbent film layer heats up by absorbing energy focused thereon and conducts heat to the tissue thereby ablating the tissue and causing it to break apart over the aperture.
5. The device of claim 1, and further comprising at least one tension member that holds the at least one energy absorbent film layer under tension over the aperture.
6. The device of claim 5, wherein the at least one tension member is comprised of a member selected from the group consisting of elastic, rubber, metal springs, or plastic springs.

7. The device of claim 1, further comprising a reservoir containing at least one drug or agent for release into the tissue.
8. The device of claim 1, wherein the support layer is comprised of: polyester, ceramic, polycarbonate (PC), polyvinylchloride (PVC), or mixtures thereof.
9. The device of claim 1, wherein the at least one energy absorbent film layer is comprised of copper pythalocyanine.
10. The device of claim 1, wherein the at least one energy absorbent film layer is anchored at ends thereof directly to the support layer.
11. The device of claim 1, wherein the at least one energy absorbent film layer is flexible so as to make contact with the tissue through the aperture when vacuum is applied over the aperture of the support layer.
12. The device of claim 1, wherein the energy absorbent film layer is responsive to energy from the group consisting of; electromagnetic energy, optical energy, gamma radiation, and/or beta radiation.
13. A method for forming openings in a tissue comprising the steps of:
 - (a) positioning a support layer having an aperture therein on a tissue;
 - (b) positioning an energy absorbent film layer over the aperture to make substantial contact with the tissue through the aperture; and
 - (c) focusing energy onto the at least one energy absorbent film layer to conduct heat to the tissue thereby ablating the tissue.

14. The method of claim 13, further comprising the step of applying vacuum over the aperture to draw the tissue into substantial physical contact with the energy absorbent film layer.
15. The method of claim 13, wherein the energy absorbent film layer breaks apart to provide access to the tissue via the aperture.
16. A method for analyzing fluid collected from tissue comprising the steps of claim 13, further comprising the step positioning an assay pad in fluid communication with the tissue via the aperture.
17. A method for delivery of at least one drug or agent into tissue comprising the steps of claim 13, further comprising the step of contacting the tissue with at least one drug or agent.
18. The method of claim 13, wherein the step of focusing energy comprises focusing energy selected from the group consisting of electromagnetic energy, optical energy, gamma radiation, or beta radiation.

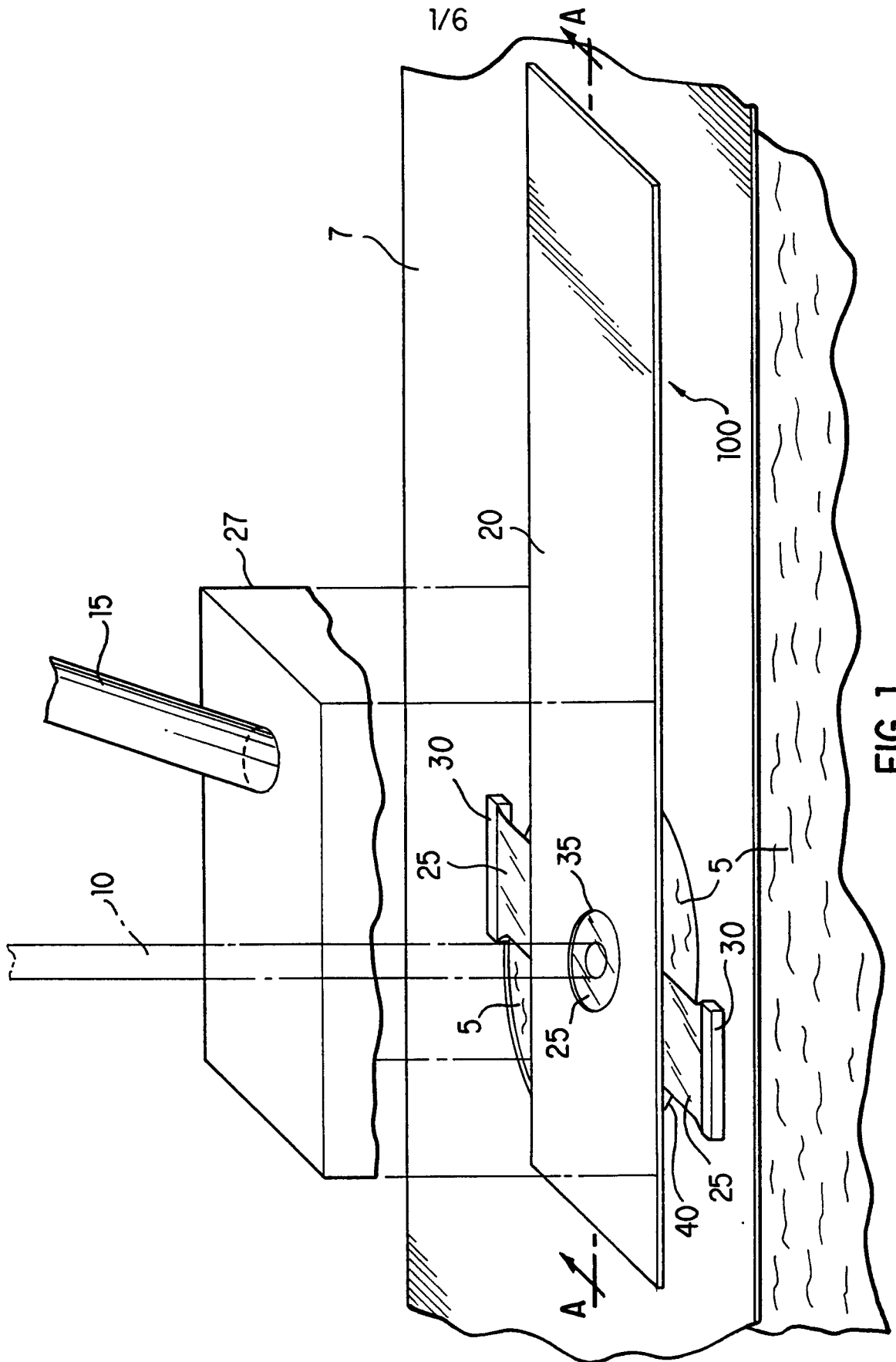


FIG. 1

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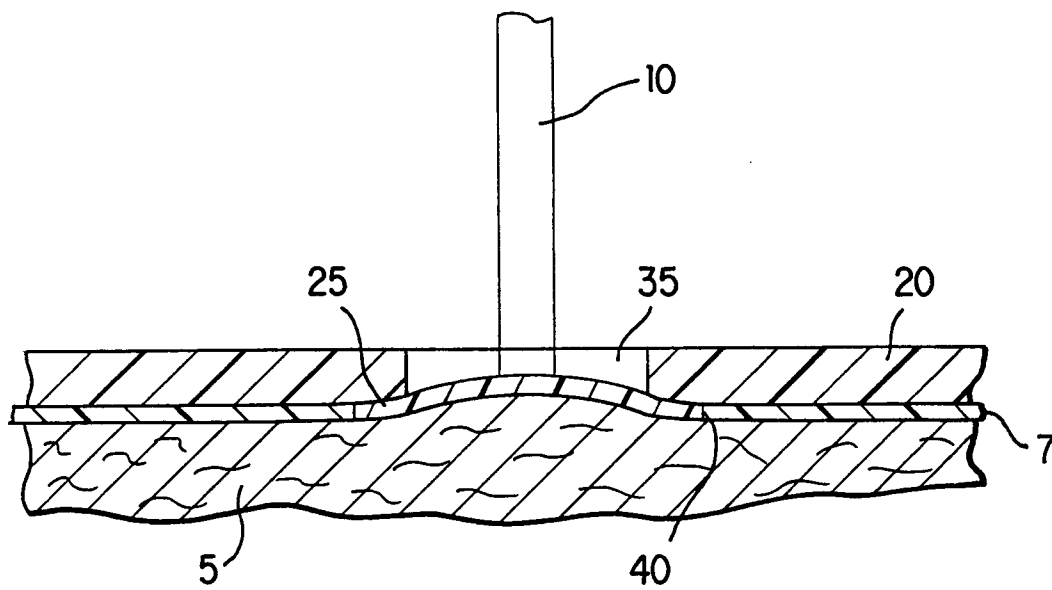


FIG. 2

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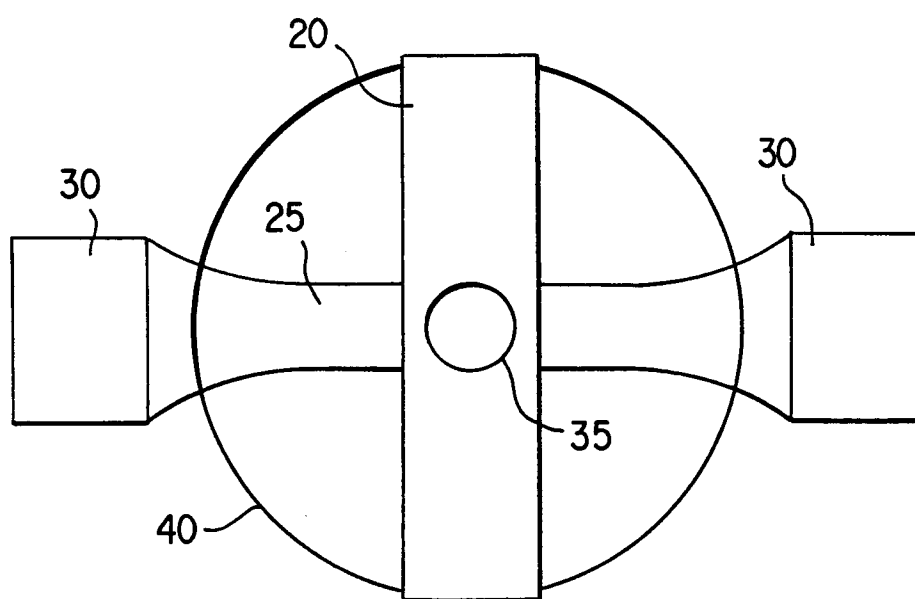


FIG. 3

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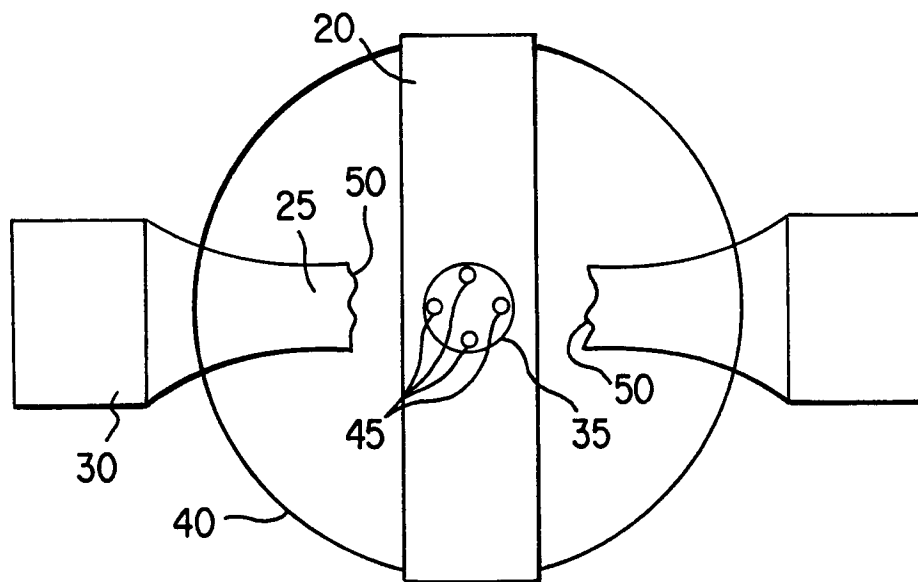


FIG. 4

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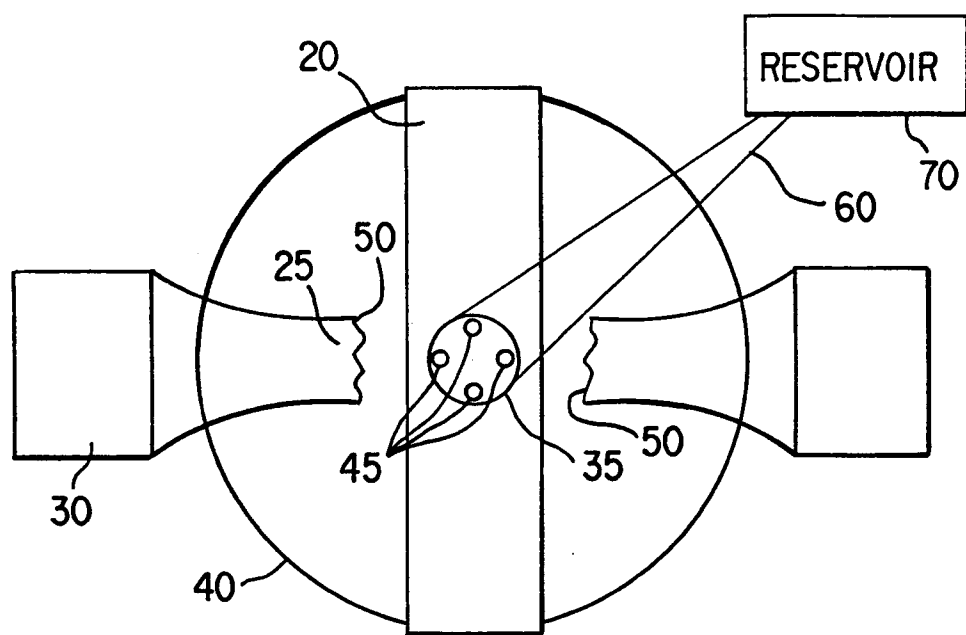


FIG. 5

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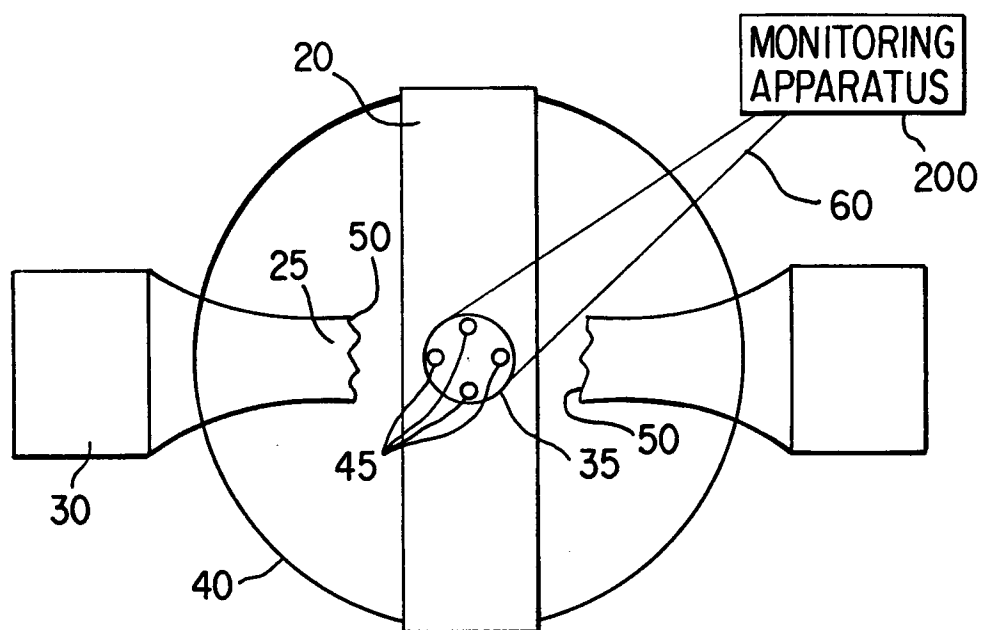


FIG. 6

INTERNATIONAL SEARCH REPORT

Int'l Application No

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A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 A61B18/20 A61B10/00 A61B5/103

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	---	7
Y	WO 98 42267 A (ABBOTT LAB) 1 October 1998 (1998-10-01) page 10, line 17 - line 24; figure 1	7
A	---	1
P,A	WO 99 40848 A (ABBOTT LAB) 19 August 1999 (1999-08-19) page 7, line 24 - page 8, line 17; figures 1,2 --- -/--	1,12



Further documents are listed in the continuation of box C.



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Y document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

& document member of the same patent family

Date of the actual completion of the international search

5 October 2000

Date of mailing of the international search report

17/10/2000

Name and mailing address of the ISA

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INTERNATIONAL SEARCH REPORT

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 885 211 A (EPPSTEIN JONATHAN A ET AL) 23 March 1999 (1999-03-23) abstract; figure 1 -----	1
A	US 4 775 361 A (BLANK IRVIN H ET AL) 4 October 1988 (1988-10-04) column 1, line 22 - line 31 -----	1

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Information on patent family members

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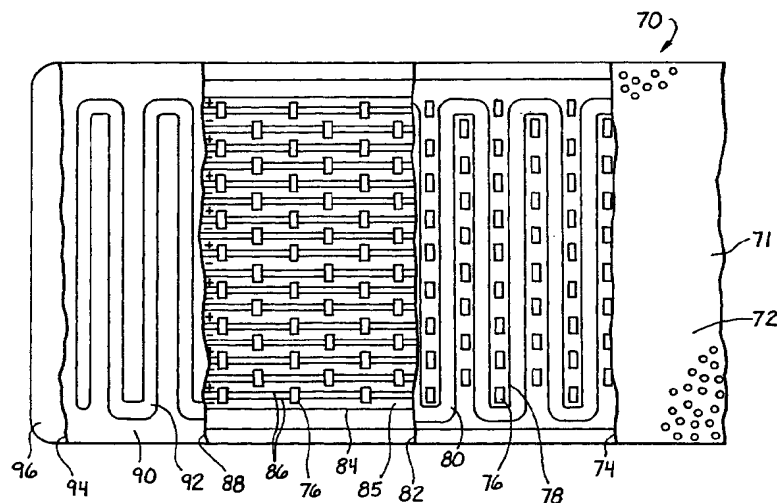
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(54) Title: FLEXIBLE ILLUMINATORS FOR PHOTOTHERAPY



(57) Abstract: A flexible illuminator (30) for external phototherapy is disclosed having at least one light generating source (76), preferably a plurality of light generating sources, on a flexible substrate (84). The flexible substrate may be a printed circuit board, and the light generating sources may be surface mount LEDs. Structure for diffusing light (111) from the discrete light sources, and/or a system for transferring heat away from a skin contact surface are provided. The illuminator may be formed as a pad (64) to be wrapped around an infant or a limb of an adult, or as a mat (60). The illuminator may be passively or actively cooled so that the skin contact surface remains below the desired temperature. The LED is preferably blue or green, and an ultraviolet filter (110) may be provided.



WO 01/14012 A1

FLEXIBLE ILLUMINATORS FOR PHOTOTHERAPY**Field of the Invention**

The present invention pertains to devices and methods of external phototherapy and, in particular, to phototherapy devices for use in close proximity or in
5 contact with the skin of the patient. More specifically, the present invention provides a flexible, high-intensity flexible phototherapy device that can be safely and comfortably worn.

Background of the Invention

10 The term "phototherapy" relates to the therapeutic use of light, and as used herein, the term "illuminator" refers to a device that is intended to be used externally to administer light to the skin for therapeutic purposes. Some phototherapy devices, in contrast, are provided on
15 probes and are designed to be used internally.

External phototherapy has been shown effective in treating various medical conditions. For example, studies have shown that certain light spectra are effective in treating bulimia nervosa, herpes, psoriasis, seasonal
20 affective disorder, sleep disorders, acne, and other conditions. One of the conditions most widely treated with phototherapy is hyperbilirubinemia in newborn infants, typified by an elevated level of a toxic molecule known as bilirubin in the infant's blood. During a natural process
25 where the body scavenges iron from a substance known as "heme," bilirubin is produced. Normally, bilirubin is conjugated within the liver and excreted. A fetus cannot conjugate bilirubin, however, so it is cleared via the placenta. During the initial neonatal period, the infant's
30 liver may be too immature to conjugate bilirubin. If the condition remains untreated, the serum bilirubin levels may

increase to the clinical condition of jaundice, since there is no effective excretory pathway. High levels of bilirubin in the neonate may cause irreversible brain damage and even death.

5 About 60 percent of newborns become clinically jaundiced at some time during the first week of life. Consequently, hyperbilirubinemia is one of leading causes of hospital readmissions of newborns. Phototherapy is the treatment of choice for neonatal unconjugated
10 hyperbilirubinemia, and has been used worldwide for decades with no known significant side effects. Phototherapy treats hyperbilirubinemia by changing bilirubin from its non-water-soluble form to water-soluble byproducts which can be bound to albumin, transported to the liver, and
15 excreted.

As a yellowish pigment, bilirubin absorbs visible light in the blue, violet, and green spectra, and most readily absorbs wavelengths in the range of 400-500 nm, with a maximum absorption peak in the 450-460 nm range,
20 i.e., blue light. Green light is also effective in phototherapy because light of longer wavelengths penetrates the skin more deeply. There is a dose-response relationship in the efficacy of phototherapy. That is, there is an increased response for higher doses of
25 therapeutic light, as shown by a decrease in bilirubin levels.

Illuminators for phototherapy which are known in the art fall into two general categories: banks of light and fiber-optic illuminators. The earliest phototherapy
30 illuminators included banks of light placed over an incubator, above an open bassinet, under a hood, or under a transparent support. Either fluorescent tubes or metal halide lamps typically serve as the light sources, although arrays of LEDs are also known in the art. These light
35 sources are spaced from the infant and illuminate the whole

body of the infant.

5 Illuminators using banks of light suffer from a number of drawbacks. The infant must wear sometimes uncomfortable eye protection during this treatment, either by using an appropriate shield or goggles, or even by taping the eyes shut, because the intense light can cause permanent eye damage. The relatively large size of the equipment takes up valuable free space in a typically cramped neonatal hospital ward. The banks of lights generate undesirable heat, and interfere with personnel attending to the patient. The heat generated is of vital concern in infant phototherapy. Newborn infants are extremely sensitive to heat, and it has been found that the heart rate of preterm infants increases significantly when the environmental temperature is raised as little as five degrees Celsius above normothermia. Hyperthermia has been associated with heart irregularities, heatstroke, and sudden infant death syndrome. Consequently, the infant's temperature must be frequently monitored when the infant is under a bank of phototherapy lights. Moreover, the relatively bulky equipment is not well-suited for home use, and thus the newborn infant must remain longer in the hospital.

25 Primarily in response to the desire of parents to bring their newborn infant home sooner, portable fiber-optic pads or wraps have been developed. These fiber-optic illuminators transmit light from a remote source through a fiber-optic cable to a flexible pad having a weave of optical fibers which can be worn next to the patient's skin. Because fiber-optic illuminators are placed around or under only a portion of the infant, its eyes are not exposed to intense light and eye protection is not necessary. Because the light source is remote from the flexible pad next to the patient, a filter can be used to attenuate any appreciable heating. Most importantly, since infant can be held and attended to while undergoing

phototherapy treatment, fiber-optic illuminators promote better infant-parent bonding during the first few weeks of life. Commercial fiber-optic phototherapy illuminators include Ohmeda's BiliBlanket and Respironics' Wallaby II, which have tungsten halogen lamps and quartz halogen lamps, respectively, as their light sources.

Figure 1 illustrates a fiber-optic pad type of illuminator of the prior art. The illuminator includes a woven fiber-optic pad 10 connected by a cable 12 to a housing 14 for a source of light. The connector 16 is affixed to an end of the cable 12 and is inserted into the housing 14 to receive the light energy. The housing 14 includes the front face 24 on which may be mounted a power switch 20, a control indicator 22, and indicator lights 26 and 28. The pad 10 comprises a plurality of optical fibers woven so as to emit light energy from one side of the pad.

Despite several advantages over radiant-type illuminators, fiber-optic illuminators are not ideal for several reasons. Significantly, fiber-optic illuminators typically deliver a lower overall amount of light than overhead banks of light, because the light is transmitted from a remote source to a relatively small fiber-optic pad. Moreover, to deliver even this limited amount of light, fiber-optic illuminators require a high-intensity light source such as halogen lamp, and an expensive optical filter to eliminate unwanted heat and ultraviolet light. Fiber-optic pads typically rely upon the geometry of the various emitting layers of fiber to control the level of light emittance. Since the patient is in direct contact with the fiber-optic pad, there is some pressure applied which may change the geometry, and thus change the level of light. Finally, the light intensity may be more concentrated near the light source than at the other end of the pad.

Recently, researchers at Stanford University have

studied the efficacy of high-intensity light-emitting diodes (LEDs) for phototherapy of hyperbilirubinemic neonates. The in vitro photodegradation of bilirubin in human serum albumin from both LEDs and conventional light sources was measured, with the conclusion that LEDs are more effective. The use of LEDs for use in home phototherapy devices was mentioned. However, no specific device structure was disclosed, nor was any consideration given for the safety and comfort of the patient, for example newborn infants, undergoing phototherapy..

In sum, fiber-optic illuminators are less effective than traditional overhead phototherapy illuminators, and both have significant disadvantages. In addition, there remains a number of hurdles, for example, relating to patient safety and comfort as well as therapeutic effectiveness, to the use of LEDs in home phototherapy devices. There thus remains a need for a phototherapy illuminator which delivers a higher intensity of therapeutic light than current fiber-optic illuminators, while retaining the advantages of a flexible light-emitting pad and being safe and comfortable in use.

Summary of the Invention

In accordance with one aspect of the present invention, an illuminator for delivering light energy to the skin for phototherapy is disclosed. The illuminator comprises a thin, lightweight flexible substrate having a plurality of conductive traces affixed thereto adapted to connect to electrical power source. At least one discrete light generating source, preferably at least two discrete light-generating sources, are disposed on the substrate and are coupled to the conductive traces. Finally, a covering at least partly surrounds the substrate and has an exterior surface that is spaced apart from the light-generating

sources, the exterior surface being adapted to contact the skin of patient. Desirably, the illuminator is sufficiently lightweight and flexible to be worn against the skin of a newborn infant without injury. The illuminator preferably includes a light diffuser to render the light energy from the discrete light-generating sources more uniform. Additionally, the cooling means is desirably provided to maintain the exterior surface below a predetermined temperature.

10 In another embodiment, the present invention provides an illuminator for delivering light energy to the skin for phototherapy, comprising a thin, lightweight substrate, a plurality of conductive traces affixed to the substrate and adapted to connect to an electrical power source, at least one light-generating source disposed on the substrate and coupled to the conductive traces, and an interface at least partly covering or adjacent the light-generating source on the substrate.

20 As used herein, the term "interface" refers to a region of the present illuminator located at least partially around and/or at least partially adjacent the light generating source or sources of the illuminator. The interface can include a hollow or open space or passage.

25 The interface advantageously provides or is adapted to carry an effective heat transfer means or medium to dissipate heat generated by the light-generating source or sources so that the illuminator can safely contact the skin of the patient, for example, a neonate. In one useful embodiment, the illuminator includes a covering and the interface provides or is adapted to carry a cooling means or medium between the covering and the substrate. For example, the interface may define spaces between the covering and a substrate for passive or active heat transfer. The illuminator may be provided in a flexible mat connected to one or more conduits carrying electrical

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wires and the cooling fluid medium.

In a still further embodiment, an illuminator of the present invention for delivering light energy to the skin for phototherapy comprises a thin, lightweight substrate and a plurality of conductive traces affixed to the substrate adapted to connect to electrical power source. At least one discrete light source, preferably at least two discrete light sources, disposed on the substrate are coupled to the conductive traces. An interface at least partly covers the light-generating sources on the substrate, and is effective to diffuse the light emitted from the discrete light source or sources. The illuminator is adapted to contact the skin of the patient. The interface may include any suitable light diffuser or diffusers. For example, light scattering elements, such as glass bubbles or hollow glass beads, and the like may be employed. Other light scattering elements include, but are not limited to, grains or particles of titanium oxide, titanium dioxide, zirconium oxide, zinc oxide, quartz, aluminum oxide, diamond dust, calcium carbonate, calcium fluoride, flint glass, barium fluoride, other glasses, material which has a refractive index different, e.g., by at least about 5%, from the refractive index of the matrix in which the light scattering elements are placed, and the like and mixtures thereof. The interface may include indentations, texturing and the like surface features to diffuse the light. A reflector or reflectors may be employed to diffuse light. Also, a lambertian (random) reflecting surface or surfaces, for example, a white surface or surfaces, may be employed to diffuse light. Of course, combinations of two or more light diffusers can be employed.

The interface may comprise a silicone matrix with glass beads or bubbles, for example, hollow glass beads, dispersed therethrough, or a blend, mixture or combination

of materials having different refractive indexes. Alternately, or in addition, the interface may have an exterior surface adapted to contact the skin of a patient, which surface is irregular, for example, having a matte
5 finish, to defuse the light emitted from the discrete light source or sources.

In one preferred embodiment of the invention, light scattering elements, such as glass bubbles and the like, are positioned in proximity to the surface of the
10 illuminator to be in contact with the patient, that is the contact surface. The light sources or sources are located further back or away from the contact surface and a flexible lambertian reflecting surface is located still further away from the contact surface. This arrangement
15 reduces the loss of light and enhances light diffusion and utilization. The illuminator is placed against the skin of the patient, leaving substantially no room for the light to escape. The reflecting surface is effective to return light scattered by the patient's tissue and/or the
20 diffusing elements back to the patient until it is absorbed, and does so at a close distance, maintaining light intensity. Concentrated light from the light source is spread over the surface of the reflector, further enhancing diffusion. This arrangement also allows the use
25 of additional diffusing material while maintaining a substantially constant level of light output.

Preferably, the average irradiance at the light emitting or contact surface of the present illuminators is more than about 50 micro watts per square centimeter.

30 In a further aspect of present invention, a wearable phototherapeutic illuminator for delivering light energy to the skin comprises a flexible substrate and a least one light-generating source disposed on the substrate. A flexible, polymer layer covers the light-generating source,
35 the layer permitting light energy to penetrate therethrough

and being adapted to substantially conform, or structured to be capable of substantially conforming, to a portion of the skin of the patient. The layer is desirably a material chosen from the group consisting of silicone, urethane, and polyurethane. There may be a plurality of the light-generating sources, and a plurality of glass bubbles, or a blend of materials having different refractive indexes, may be dispersed throughout the layer to defuse the light emitted from the light-generating sources.

Each of the features disclosed herein is included within the scope of the present invention. In addition, all combinations of two or more of the presently disclosed features which are not mutually inconsistent or incompatible are also included within the scope of the present invention.

These and other aspects and advantages of the present invention are apparent in the following detailed description and claims, particularly when considered in conjunction with the accompanying drawings in which like parts bear like reference numerals.

Brief Description of the Drawings

Figure 1 is a perspective view of a prior art fiber-optic illuminator;

Figure 2 is a perspective view of a flexible pad-type illuminator of the present invention;

Figure 3 is a schematic view of a phototherapy system utilizing a flexible pad-type illuminator of the present invention;

Figure 3A is a schematic illustration of the control housing of the phototherapy system shown in Figure 3;

Figure 4 is a perspective view of alternative mat-type illuminator of the present invention;

Figure 5 is a perspective view of a flexible pad-type

illuminator of the present invention wrapped around an adult limb;

Figure 5A is an illustration of an illuminator of the present invention in the form of a mask to be worn on the face of an adult or adolescent human.

Figure 6 is a plan view of a pad-type illuminator of the present invention showing sequential layers cutaway;

Figure 7 is a sectional view through a portion of the illuminator of Figure 6;

Figure 8 is a sectional view through a portion of an alternative illuminator similar to that shown in Figure 6;

Figure 9 is a plan view of a substrate and electronic connections for a plurality of light-generating sources used in an exemplary illuminator of the present invention;

Figure 10 is a partial cutaway view of internal cooling channels formed in an exemplary illuminator of the present invention;

Figures 11A-11D are cross-sectional views showing various constructions of the illuminator of the present invention;

Figures 12A-12F are cross-sectional views showing further constructions of the illuminator of the present invention;

Figures 13A-13D are cross-sectional views showing still further constructions of the illuminator of the present invention;

Figures 14A-14C are plan views of illuminators of the present invention having passive cooling channels therein;

Figures 15A-15C are perspective views of illuminators of the present invention having external cooling fins formed thereon; and

Figure 16 is a perspective view of an alternative illuminator having internal spacer pins.

Figure 17 is a perspective illustration showing a still further construction of an illuminator in accordance

with the present invention.

Figures 17A-D are schematic illustrations of various patterns useful in the construction illustrated in Figure 17.

5 **Description of the Preferred Embodiments**

10 The present invention provides a flexible illuminator having a variety of applications, such as for the treatment of hyperbilirubinemia in neonates, and psoriasis, seasonal affective disorder, sleep disorders, herpes, acne, and other medical conditions. The invention is an advance over current fiber-optic type illuminators because of the increased intensity of the light sources. Various configurations are described herein, none of which should be construed as particularly preferred in general.

15 Instead, each configuration may be preferred in certain applications over others.

Illuminator System

20 Figure 2 illustrates an illuminator 30 of the present invention comprising an elongate flexible body 32 having a front or contact surface 34 and a back surface facing the opposite direction and not seen in Figure 2. In the embodiment illustrated, the illuminator 30 has a rounded rectangular configuration with a length L, a width W, and a thickness t, with the length L being substantially greater than the width W, both of which are substantially greater than the thickness t. The proportion of these dimensions is preferred to enable the illuminator 30 to be wrapped around a small infant, or around the limb of an adult, as seen in Figures 3 and 5, although those of skill

25 in the art will understand that other configurations are possible.

30 As will be described in more detail below, the illuminator 30 contains a plurality of electric light-

generating sources, and thus a power cable 36 attaches to a first narrow end 38 of the body 32. The body 32 is thicker in a region 40 adjacent the first end 38 to provide strain relief at the interface between the body and cable 36. In one particular preferred embodiment, the body 32 is molded around the light-generating sources and power cable 36, with the thickened region 40 being formed accordingly. As will also be described below, the illuminator 30 may include means for transferring heat away from the front surface 34, which may involve flow of a cooling medium to interior channels formed in the body 32. In that case, the jacket around the power cable 36 may also provide a conduit for delivery of the cooling medium to and from the illuminator 30.

Illuminator Configurations

Figures 3, 3A, 4, 5 and 5A illustrate several potential configurations of the illuminator of the present invention. In Figure 3, an illuminator 44 similar to that shown in Figure 2 is wrapped completely around the abdomen of an infant patient. The illuminator 44 may be secured in this position using straps, Velcro, adhesive tape adhered to a disposable cover, or other such attachment means. A cable 46 supplies electricity and cooling medium from a control housing 48 to the illuminator 44, as mentioned above. Figure 3 schematically illustrates a control assembly 49 (of conventional design) providing electricity to illuminator 44 through power conduit 51. Control assembly 49 also controls the operation of an active cooling system 50 including a source of cooling medium 52 and a pump 54. Source 52 may include cooling coils or other suitable assembly for maintaining the temperature of the cooling medium or coolant at a desired level. A pair of conduits 56 and 57 deliver the cooling medium to the illuminator 44 and return medium to be cooled to the system

50.

Figure 4 illustrates a larger, mat-type illuminator 60 upon which an infant may be placed. A single cable 62 supplies power (and possibly cooling medium) to the illuminator 60.

Figure 5 illustrates a pad-type illuminator 64, much like the illuminator 30 illustrated in Figure 2, that is wrapped around the patient's limb and fastened with Velcro hook/loop fastener patches 66. Again, a single conduit 68 delivers power and potentially cooling medium to the illuminator 64.

Figure 5A illustrates a further specialized form of an illuminator in accordance with the present invention. This illuminator 61 is in the form of a mask to be placed on the face of an adult or adolescent human. An elastic band 63 is attached to mask 61 and is placed around the patient's head to secure the mask in a desired position on the face. Eye holes 65, nose hole 67 and mouth hole 69 are provided so that the eyes can be protected from the light and normal breathing/talking can occur while the patient is being treated, for example, for acne. A single conduit 59 delivers electrical power and possibly cooling medium to the mask 61.

Illuminators in accordance with the present invention can be formed into any suitable configuration to treat various medical conditions, as described herein, while also protecting the patient from unwanted, and possibly harmful exposure to light and/or heat. For example, the present illuminators can be configured to be placed on the face, like a wash cloth, for the treatment of seasonal affective disorder, as well as acne and other skin conditions; or can be configured similarly to a sanitary napkin, tampon or condom for the treatment of herpes.

In short, the forms of the present illuminators illustrated are not intended, and should not be taken, to

be limiting.

Exemplary Illuminator Construction

Figures 6-7 illustrate the internal construction of an illuminator similar to that shown in Figure 2. The plan view of Figure 6 shows one end of the body 70 of the illuminator with sequential layers stripped away from right to left. These layers can be seen in cross-section in Figure 7. The front or contact surface 71 of the body 70 faces out of the page in Figure 6. Therefore, a front covering 72 is seen on the right side of Figure 6, and is cut away at line 74 to reveal an array of light-generating sources 76. A plurality of glass bubbles 73 (right side of Figure 7) are randomly located in front covering 72 to scatter or diffuse light, as discussed hereinafter. In this embodiment, a plurality of transversely extending spacers 78 surround the sides of each of the light-generating sources 76, and are spaced from one another to provide cooling channels 80 therebetween. The spacers 78 may or may not at least partially encapsulate the sources 76. Such encapsulation is preferred to enhance dissipation of heat and light diffusion, and to protect the light sources from physical damage and/or detachment. As is apparent from Figure 6, the cooling channels 80 extend in a serpentine fashion along the length of the body 70. The layer of spacers 78 is cut away at line 82 in Figure 6 to reveal a substrate 84 on which the light-generating sources 76 are mounted. In addition, an array of conductive traces 86 is provided on the substrate 84 to power the light-generating sources 76. Continuing to the left in Figure 6, the substrate layer is cut away at line 88 to reveal a layer of secondary spacer material 90 within which is formed a secondary cooling channel 92. Again, the cooling channel 92 extends in a serpentine fashion along the length of the body 70 and adjacent the substrate. Finally, the

secondary spacer material 90 is cut away at line 94 to reveal a back cover 96.

Alternative Illuminator Construction

Figure 8 illustrates, in cross-section, an illuminator 100 having a substrate 102 with a plurality of light-generating sources 104 mounted thereon. An array of spacers 106 between cooling channels 108, as in Figure 7, is provided. In addition, an insulating layer 110 and outer covering 112 are included in the combination of components making up the interface. Also included are a plurality of glass bubbles 111 located in a relatively well defined layer in outer covering 112 to scatter or diffuse light, as discussed hereinafter. As with Figure 7, the backing comprises the secondary spacer 114 and secondary cooling channels 116 encompassed by the back cover 118. The addition of an insulating layer 110 further helps to prevent heat transfer from the light generating sources 104 to the contact surface of the illuminator.

Internal Illuminator Systems

Figure 9 is a cutaway view of one end of an illuminator 120 of the present invention showing the interface between a power cable 122 and an array of conductive tracings 124 providing a conductive path to a plurality of light-generating sources 126. A wire 128 electrically connects to a pole 130 that is in electrical communication with the negative terminal of each of the light-generating sources 126. Likewise, a wire 132 electrically connects to a pole 134 that is in electrical communication with the positive terminal of each of the light-generating sources 126. The wires may be electrically connected to the tracings by lap soldering to the pole or bus bar or through use of DIMM or MOLEX-type multiconductor connectors. In this embodiment, the light-

generating sources are provided in seventeen rows across the width of the illuminator 120, and are staggered from column to column. That is, a first column 136 of nine light-generating sources is followed by a second column 138 of eight light-generating sources in different rows of conductive tracings 124. This pattern repeats itself along the length of the illuminator 120.

Figure 10 illustrates the relative positions of the light-generating sources 126, a first cooling channel 140, and secondary cooling channel 142 provided below the substrate. Arrow 144 indicates an inflow of cooling medium to the first cooling channel 140, which medium flows between columns of light-generating sources 126. The horizontal cutaway line 146 reveals the secondary cooling channel 142 below the substrate. Although not shown, the first cooling channel 140 is in fluid communication with the secondary cooling channel 142 at the opposite end of the illuminator. That is, the cooling medium flows along the length of the illuminator 120 (from right to left), and then passes across the plane of the substrate (i.e., into the page) through an opening into the secondary cooling channel 142. The cooling medium then flows (from left to right) along the length of the secondary cooling channel 142 until it exits the illuminator, as indicated by arrow 148.

Figure 10 thus illustrates active cooling of the illuminator 120, wherein cooling medium is propelled through internal channels. The cooling medium in this regard may be in liquid or gaseous form, with air being preferred to avoid increasing the weight of the illuminator 120 in use. Of course, other arrangements of cooling means are possible, as will be described in more detail below.

Functional Considerations

Now with reference more particularly to the cross-

section of Figure 7, the illuminator can be viewed more generally as including the light-generating sources 76 mounted on the substrate 84, and an interface provided between the substrate 84 and a front or contact surface 98.

5 In the illustrated embodiment, contact surface 98 comprises the outer surface of the covering 72, while the interface comprises a combination of the covering, the spacers 78, and the cooling channels 80. In addition, the illuminator preferably includes a backing, which in this embodiment
10 comprises the secondary spacers 90, secondary cooling channels 92, and back cover 96. The invention may be best described in terms of the preferred functional characteristics of the interface and the backing, as follows.

15 The interface preferably performs two main functions: heat insulation and light diffusion. That is, the separate light-generating sources 76 generate some heat in operation which must be intercepted and carried away or attenuated before it reaches the contact surface 98. Therefore, the
20 interface preferably provides a thermal barrier to heat conduction, and may also include a system of passive or active cooling, facilitated by the cooling channels 80. In addition, the light-generating sources 76, being discrete and spaced apart, create a plurality of points of intense
25 light, rather than an even distribution. Therefore, the interface preferably diffuses the discrete points of light to provide a more uniform emittance. In addition, the interface performs other functions. For example, the interface protects the light sources and circuitry from
30 damage and/or detachment, reduces or even eliminates the risk of exposing the patient to electrical current, and provides additional padding to enhance the comfort of the patient.

The backing preferably performs two main functions as
35 well: heat conduction and light reflection. That is, the

backing preferably provides an effective heat sink for the heat generated by the light-generating sources 76, which works in conjunction with the heat barrier provided by the interface to cause heat to travel away from the contact surface 98. In this manner, the secondary spacer 90 is preferably made out of a highly conductive material that is in intimate contact with the backside of the substrate 84. The backing also protects the circuitry and light sources, protects the patient from electrical current and provides added padding to enhance patient comfort.

As will be apparent from the variations in construction that follow, numerous combinations of the interface and backing are possible. Because of the numerous configurations that the illuminator can take, as seen for example in Figures 3-5, there is no single optimum construction, but rather the functional characteristics described above are desirably provided in the most cost-effective manner for the particular application. Thus, for example, if the illuminator is to be used as a mat, as seen in Figure 4, additional padding between the substrate 84 and light-generating sources 76 may be required, which will increase the thickness of the interface and/or backing. Similarly, for an elongated pad-type illuminator, as seen in Figures 2-3 and 5, padding is not as important as the illuminator being flexible and lightweight. Additionally, the contact surface of the illuminator must be relatively soft and preferably hypoallergenic if it is to be used for treatment of hyperbilirubinemia in neonates.

The illuminator may be formed into a variety shapes, such as a pad or mat shown. Alternatively, the illuminator can be formed into a belt, a wrap, a cushion or pillow, a collar, a blanket, a strap, a vest, or any other desired shape. Advantageously, the particular shape and ultimate configuration on the patient does not affect the quality and intensity of the light delivered, as with prior fiber

optic devices.

Light Diffusion

At least a portion of the interface preferably causes the light emitted by the plurality of light-generating sources to be diffused or directed as desired. Such diffusion or direction is effective to provide a more uniform, constant and intense light pattern on the contact surface relative to a similar apparatus including a plurality of discrete light emitting sources without light diffusion. Therefore, the interface may be made of a single material or blend of materials having different refractive indices, such as silicone and glass bubbles or silicone and titania. Thus, in Figure 7, the front cover 72 comprises a matrix of silicone within which a plurality of glass bubbles is randomly impregnated. Figure 8 illustrates a cover 112 which comprises a matrix of silicone having a plurality of more evenly distributed glass bubbles 111. It should be noted that the size of the glass bubbles in the figures is exaggerated for illustration purposes. Alternatively, or in addition, the covering 72 or 112, or the insulating layer 110, may be provided with deformities or markings formed by mechanical, chemical, or other means to cause light emitted by the light-generating sources to diffuse. Such deformities or markings can be formed by molding, cutting, hot stamping, etching, painting, machining, coating, forming, milling, or printing. The deformities may vary in density, opacity, shape, color, index of refraction, size, depth and shade so as to produce a desired diffusion or light distribution. In one embodiment, such surface deformities are created by roughening the surface of the cover mold with glass beads or sand so as to give the surface a matte finish. The interface, such as the covering, may vary in color, index of refraction, or shape along the length of the

illuminator. A reflector or reflectors may be used to diffuse light. Lambertian reflectors also can be used. Prismatic films and diffusers, lenticular lenses, coatings, and other systems or materials may be used to cause light to be diffused as desired. Reflective paints or coatings, such as coatings of magnesium oxide, aluminum oxide, other white powders and the like and mixtures thereof, are useful for diffusion.

Figures 17, 17A, 17B, 17C and 17D illustrate the use of such paints or coatings. An LED 504 is shown positioned relative to a light reflecting surface 506 of illuminator 510 in accordance with the present invention. Reflecting surface 506 can be a metallized surface or a surface with a matte finish or the like. Contact surface 512 is part of the interface of illuminator 510 and is spaced apart from LED 504. Arc 514 is a representation of the intense light pattern on contact surface 512 generated by LED 504 with no light diffusion. The light within arc 514 is very intense while the light from LED 514 outside the arc is substantially less intense and may not be therapeutically effective.

Figure 17A illustrates a pattern of white dots 520 that can be painted or coated on contact surface 512 within the arc 514 to diffuse the intense light. The diameter of the dots decreases from the center of the pattern outwardly. This pattern of dots 520 scatters and/or reflects some of the light back to the reflecting surface 506. The pattern of dots depends, for example, on the thickness of the layer on which the contact surface is located and its distance from LED 504, and the presence of any additional light diffusing material or materials in the interface. The pattern of dots 520 results in a substantially more diffuse, yet therapeutically effective light pattern on the contact surface 512.

Figures 17B, 17C and 17D illustrate alternate coating

patterns that can be used in place of dots 520. Thus, a pattern of rectangles 522, a pattern of outwardly radiating lines 524 or a series of circles 526 can be used in much the same way as dots 520 to provide for enhanced light diffusion.

The interface may also comprise filters to reflect or absorb certain wavelengths of light. In order to control the exposure of the patient to ultraviolet radiation, or to minimize the deteriorative effect of such radiation on the illuminator, a layer or coating of or containing an ultraviolet absorber may be used. For example, the insulating layer 110 shown in Figure 8 may instead represent an ultraviolet filter. Examples of ultraviolet absorbers include bezophrenones, benzotriazoles, and salicylates. In addition, the illuminator made further comprise additives, including infrared absorbers (e.g., metals), antioxidants, coloring agents, plasticisizers, stabilizers, and antistatic agents.

Flexible Substrate

The present invention utilizes any type of flexible circuitry substrate known in the arts. Typically, the term "flexible substrate" pertains to polymeric sheets which may be bent or rolled without breaking. In one embodiment, the substrate may be said the flexible if it can be rolled, without breaking, into a cylindrical tube having a diameter less than 30 cm, and more preferably less than 5 cm. Examples of such flexible substrates are flexible printed circuitry laminates, which are composites of methyl conductors and dielectric substrates bonded together by an adhesive system. Other flexible substrates may not use adhesives, such as copper foil which is electrolytically deposited or rolled-annealed.

The substrates should be flexible and cable of withstanding the heat generated during the manufacturing

process and by the light-generating sources. Consideration should also be given to the dimensional stability, chemical resistance, electrical properties, flame retardancy, and cost. Substrates can be either thermosetting or thermoplastic polymers, such as polyester and polyimide films.

If an adhesive is used to secure the conductive tracings to the substrate, consideration should be given to the thermal properties of the adhesive. Desirably, the adhesive is highly heat conductive to further facilitate conduction of the heat generated by the light-generating sources throughout the substrate and to adjacent heat sinks.

The flexible substrate may comprise a reflector on the side facing the contact surface for directing light from the light-generating sources toward the contact surface. The reflector may be a thin, flexible sheet adhered to the flexible substrate. Alternatively, the reflector may be comprised of reflective materials coated directly on the flexible substrate. The reflector is desirably perforated in the locations of the light-generating sources and may be coated to reflect an appropriate wavelength or range of wavelengths of light. The reflective materials may be metals such as aluminum, silver or gold (or alloys thereof), or dielectrics coated at thicknesses designed to reflect desired wavelengths, or reflective paint. In one embodiment, the reflector provides lambertian reflectance, for example, reflects light by using a paint or coating which is white or matches the color of the LEDs.

Conductive Tracings

The flexible substrate may be coated, cast, deposited, or otherwise adhered to the conductive tracings or vice versa. In a preferred embodiment, the conductive tracings are directly adjacent to and in contact with the flexible

substrate. Alternatively, one or more additional layers may be present between the conductive traces and flexible substrate, such as when adhesives are used. The conductive tracings may be a variety of materials, including rolled-annealed copper, electro-deposited copper, silver, gold, aluminum, iron, steel, solder, or any other metal or conductor. The conductive coating may be applied as, or processed into, tracings using any means for application or removal, including chemical, mechanical, and optical means, as well as the use of lasers. In a preferred embodiment, a plurality of pairs of parallel conductive traces are etched into the rolled-annealed copper coating of a flexible substrate, for example, using conventional photo-etching techniques.

Polymer thick films including one or more finely divided conductive materials like silver, nickel, or carbon in a polymer binder like polyester, epoxy, acrylic, or vinyl also may be used. Polymer thick film printed wiring is less expensive than copper conductors since it is generally formed in a single step using screen printing, without traditional plating, etching, stripping, and cleaning. Examples of polymer thick films which offer an alternative to other types of circuitry are available from Du Pont as the CB[®] series polymer thick film pastes.

An insulating film or coating may be applied over the conductor surface to protect the circuitry for moisture, contamination, and conductor damage, and to reduce stress on the conductors during flexing. These protective coatings may be overlays comprising an insulating film coated with an adhesive, a coating comprising liquid polymers applied to the circuit, leaving the pad areas exposed, and solder masks comprising film laminates into which conductor access holes have been formed. Adhesives such as epoxies and polyimide resins may be used for overlays and laminations.

Light-generating Sources

The light-generating sources are preferably a light-emitting diode (LED) chip or die of the surface mount variety. Alternatively, other types of LEDs, lasers, and laser diodes also may be suitable. The light-generating sources may be multicolored LEDs, or a combination of multiple colored LEDs, a combination of different LEDs, or arrangement of the same type of LEDs, depending on the desired color, distribution or pattern.

For the treatment of neonatal hyperbilirubinemia, the preferred color of LEDs is blue, although green LEDs also may be effective. The treatment of other conditions may require different colored LEDs. For example, herpes may be most effectively treated by red LEDs, seasonal affective disorder may be treated by white or yellow LEDs, and psoriasis may be treated by ultraviolet LEDs.

The illuminator of the present invention may include any suitable interconnection technology to provide an electrical circuit among the LEDs, the substrate, the power supply, and any control device. In this regard, flexible or traditional wiring, solder attachment, conductive pieces, and/or pressure connectors may be used. A preferred embodiment utilizes surface mount technology to adhere the light-generating sources to the flexible substrate. Such manufacturing technologies may comprise surface mount-on-flex (SMT), chip-on-flex (COF), flip chip-on-flex (FCOF), micro-surface mount technology (micro SMT), micro-ball grid array (micro BGA), controlled collapsed chip connection (C4), or any known method of manufacture or assembly.

Illuminator Control

The illuminator may comprise a controller capable of making the light-generating sources separately addressable so that they may be selectively illuminated in a particular

pattern to achieve a particular therapeutic result. In addition, the power level of one or all of the light-generating sources may be controlled to optimize the light intensity required, to mix colors where different LEDs are used, or to shut off light-generating sources in the case of overheating. In the latter instance, thermocouples may be provided in and around the light-generating sources, or on the contact surface, to monitor the temperature of the illuminator and provide feedback to the controller. Finally, the illuminator controller may contain a timer to assist in metering exposure of the patient according to doctor's instructions.

Cooling Means

The interface of the illuminator preferably occupies the space between the substrate and the external contact surface. The interface may contain fins, vanes, ridges, grooves, tubes, holes, channels, or other features to absorb or diffuse heat, to increase surface area for heat exchange, and/or to control or direct a flow of air, water or other fluids. Alternatively, the interface may be solid if heat is not a concern.

As will be apparent from the structural variations shown herein, the illuminator may include holes or spaces through the substrate, covering, or between the covering and substrate in locations which avoid interference with the conductive traces, light sources, and cooling fluids. The illuminator may utilize air or water, and an associated blower or pump to force the cooling fluid through spaces.

The interface may be made of silicone, urethane, polyurethane, or any flexible plastic or other translucent or transparent material, or colored material, and combinations thereof. As mentioned above, silicone with at least a portion having glass bubbles and/or titania impregnated therein is preferred.

Disposable Overwrap

The illuminator is desirably at least partly surrounded with a disposable overwrap as a contamination barrier between the illuminator and the skin of the patient. Such an overwrap may be thin polyethylene or cellophane, for example, and is preferably transparent so as not to interfere with the transmission of light to the patient. The overwrap is preferably loosely fitted over the illuminator in any form, and can be easily secured by tape or other means and removed for sanitary purposes and subsequent immediate re-use of the illuminator.

Alternative Illuminator Constructions

Figures 11-13 illustrate various cross-sections of illuminators in accordance with present invention showing the basic elements of a substrate, a light-generating source (in this case an LED), an interface between the substrate to a contact surface, and a backing. Consistent with the discussion above regarding the functional characteristics, these variations are helpful in illustrating the multiple permutations of materials and configurations that are possible in constructing an illuminator of the present invention.

Figures 11A-11D illustrates four cross-sections that all have a substrate 160, an LED 162, and an interface comprising a solid layer 164 of light-diffusing and heat-insulating material. The layer 164 has an exterior skin contact surface 166. One example of material for the layer 164 is silicone having glass bubbles distributed randomly throughout. Another example of material for the layer 164 is silicone having titania distributed throughout. Alternatively, or in addition, the layer 164 may be silicone having a matte finish on the skin contact surface 166. The skin contact surface may have a pattern, for example, a printed pattern, effective to scatter and

diffuse light.

In Figure 11A, the backing comprises a solid layer 168 of light-reflective, heat-conductive material. Figure 11B includes a backing comprising a solid layer 170 of light-
5 diffusive, heat-conductive material. In Figure 11C, the backing comprises a back cover 172 spaced from a substrate 160 with a secondary spacer 174. The secondary spacer 174 includes gaps or channels 176 therein directly across the substrate 160 from each of the LEDs 162. In Figure 11D,
10 the backing comprises a back cover 178 spaced from the substrate 160 with a secondary spacer 180. In this case, the secondary spacer 180 is provided directly underneath each of the LEDs 162, and preferably is made of a highly heat conductive material. Heat thus flows from the LED 162
15 through the substrate to the secondary spacer 180, which is cooled on either side by the gaps 182.

Figures 12A-12F all include the substrate 160, LED 162, and a front cover 190 whose exterior surface is intended to contact the skin of patient. In addition, each
20 of the cross-sections in Figures 12A-12F include one or more gaps or channels for cooling.

In Figure 12A, the cover 190 is spaced from the substrate 160 with a spacer 192. The spacer 192 is formed directly over the LEDs 162 and defines gaps or channels
25 194. The backing comprises a solid layer 196 of light-reflective, heat-conductive material. In Figure 12B, the interface includes the aforementioned spacer 192 and channels 194, as in Figure 12A, but the backing comprises a back cover 198 spaced from the substrate 160 with a
30 secondary spacer 200. In this embodiment, the secondary spacer 200 provides gaps or channels 202 directly underneath each of the LEDs 162.

Figure 12C shows a spacer 204 separating the cover 190 from the substrate 160, the spacer 204 providing gaps or
35 channels 206 directly surrounding each of the LEDs 162. In

this embodiment, the interface is formed by the cover 190, spacer 204, and channels 206, and the cooling medium can flow directly over each of the LEDs 162. Again, the backing is provided by a solid light-reflective, heat-conductive layer 208. Figure 12D also illustrates the spacer 204 and channel 206, which together with the cover 190 comprise the interface, but the backing is provided by a spacer 210 and a back cover 212. The spacer 210 is directly underneath each of the LEDs 162 and forms gaps or channels 214 therearound.

Figures 12E and 12F are substantial mirror images of one another, each of which having cooling channels above and below the substrate 160. In Figure 12E, the interface comprises the cover 190, the spacer 220 directly surrounding each of the LEDs, and gaps or channels 222 defined by the spacer. The backing comprises a secondary spacer 224 directly underneath each of the LEDs 162, a back cover 226, and a plurality of gaps or channels 228 adjacent the secondary spacer. In Figure 12F, a spacer 230 separates the cover 190 from the substrate 160 and defines cooling gaps or channels 232 directly over each of the LEDs 162. The backing comprises a secondary spacer 234 separating a back cover 236 from substrate 160 and defining a plurality of cooling gaps or channels 238 directly underneath each of the LEDs 162.

Figures 13A-13D illustrates several illuminator cross sections with maximum spaces defined by vanes or walls between two covers. More specifically, each of the cross-sections in Figures 13A-13D includes the substrate 160, LED 162, a front cover 250, and a back cover 252.

Figure 13A includes a plurality of vanes or walls 254 spacing the front cover 250 from the substrate 160. Cooling gaps or channels 256 are defined by the walls 254 surrounding each of the LEDs 162. The backing comprises the back cover 252 spaced from the substrate 160 by

secondary walls 258. Again, and gaps or channels 260 are provided below the substrate for cooling purposes.

In the embodiment of Figure 13B, walls 262 extend between the front cover 250 and a coating layer 264 provided on top of the substrate 160. The coating layer extends into contact with each of the LEDs 162. As in Figure 13A, the walls 262 defined gaps or channels 266 surrounding each of the LEDs 162. The backing comprises secondary walls 268 extending between the back cover 252 and a coating 270, and gaps 272 provided directly underneath each of the LEDs 162.

Figure 13C is similar to that shown in Figure 13B and includes walls 274 extending between the front cover 250 and a layer 276 formed on the substrate 160. In this case, the layer 276 completely covers each of the LEDs 162. Cooling gaps or channels 278 are formed over each of the LEDs, and the covering protects each of the LEDs from the corrosive effect of a fluid cooling medium. Also, as in Figure 13B, the backing comprises secondary walls 280 spacing the back cover 252 from a layer 282 formed on the backside of the substrate 160. Again, cooling gaps 284 are provided below each of the LEDs.

Finally, Figure 13D includes a spacer 290 extending between the substrate 160 and a front cover 250. The spacer 290 covers the substrate 160, as at 292, but provides gaps or channels 294 for cooling. The backing comprises a secondary spacer 296 extending between the substrate 160 and the back cover 252, the spacer being generally solid but defining gaps or channels 298 directly below each of the LEDs 162.

Passive Cooling

Up to now, various configurations of illuminators of the present invention have been described having internal gaps or channels, the understanding being that cooling

medium actively flows therethrough. While active cooling is certainly one option, a less-expensive variant is passive cooling. Figures 14A-14C illustrate three embodiments of an illuminator pad having passive cooling channels therethrough.

Figure 14A illustrates an illuminator pad 300 having a plurality of columns of apertures 302 extending from the front side to the back side. Preferably, the columns of apertures 302 are formed in between each column of LEDs 304 for maximum heat dissipation. Of course, the apertures should avoid interference with any copper tracings or light sources. Figure 14B illustrates an illuminator 306 having a series of channels 308 extending along the width dimension. The channels 308 are desirably formed between each column 310 of the LEDs. Finally, Figure 14C illustrate an illuminator 312 having a series of longitudinal channels 314 formed therein. In all of the embodiments seen in Figures 14A-14C, the apertures or channels are open at both ends and serve to passively dissipate heat generated by the LEDs.

Another configuration facilitating passive cooling is the use of external fins, as seen in Figures 15A-15C. In particular, Figure 15A illustrates an illuminator 320 having a plurality of fins 322 extending in the width dimension. In Figure 15C, the external fins 324 extend in the longitudinal dimension. Finally, in Figure 15C, the fins extend both in the width and longitudinal dimensions in a waffle pattern. Also, as shown in Figure 15A, the fins 322 are located on both the top and bottom surfaces of the illuminator. Of course, the fins, if present at all, can be located on the top and/or bottom surfaces of the illuminator. These fins provide passive cooling for the illuminators, and may be provided on the front or rear surfaces, or both.

A still further variation of passive cooling is seen

in the illuminator 340 of Figure 16. For illustration purposes, the cover 342 of the illuminator 340 is shown in phantom to reveal a plurality of pins or spacers 344 extending between the substrate 346 and cover 342. The side edges of the illuminator 340 remain open to permit passive cooling of the LEDs 348. Alternatively, the side edges may be closed and cooling medium flowed through conduit 350. In any event, the spacers 344 maintain a gap between the front cover 342 and the substrate 346 along the length of the illuminator 340.

While this invention has been described with respect to various specific examples and embodiments, it is to be understood that the invention is not limited thereto and that it can be variously practiced within the scope of the following claims.

WHAT IS CLAIMED IS:

1. An illuminator for delivering light energy to the skin of a patient for phototherapy, the illuminator comprising:

a thin, lightweight flexible substrate;

a plurality of conductive traces affixed to the substrate and being adapted to connect to an electrical power source;

at least one discrete light-generating source disposed on the substrate and coupled to the conductive traces; and

a covering at least partly surrounding the substrate and having an exterior surface that is spaced apart from the light-generating sources, the exterior surface being adapted to contact the skin of a patient.

2. The illuminator of claim 1, wherein the illuminator is sufficiently lightweight and flexible to be worn against the skin of a newborn infant without injury.

3. The illuminator of claim 1, which includes a plurality of discrete light-generating sources disposed on the substrate and coupled to the conductive traces.

4. The illuminator of claim 1, wherein the covering is configured to facilitate the effective dissipation of heat produced by the light-generating sources away from the skin of the patient.

5. The illuminator of claim 4, wherein the covering includes fins positioned to provide increased dissipation of heat produced by the light-generating sources away from the skin of the patient relative to a substantially identical covering without the fins.

6. The illuminator of claim 4, wherein the covering is spaced from the substrate and further including cavities between the covering and the substrate.

7. The illuminator of claim 1, wherein the covering at least partly defines an internal structure adapted to facilitate at least one of a) dissipation of heat produced by the light-generating sources away from the skin of the patient, and b) diffusion of light generally toward the skin of the patient.

8. The illuminator of claim 1, further including a reflector for reflecting light from the light-generating sources away from the substrate toward the patient.

9. The illuminator of claim 8, wherein the light-generating sources comprise surface mount LEDs, and the reflector comprises a thin, flexible sheet perforated with holes through which the LEDs project.

10. The illuminator of claim 1, further including cooling means for effectively dissipating heat generated by the light-generating sources so that the illuminator can safely and comfortably contact the skin of a patient.

11. The illuminator of claim 1, further including a disposable overwrap sized to at least partly surround the illuminator and provide a contamination barrier between the illuminator and the skin of the patient.

12. An illuminator for delivering light energy to the skin of a patient for phototherapy, the illuminator comprising:

a thin, lightweight substrate;

a plurality of conductive traces affixed to the

substrate and being adapted to connect to an electrical power source;

at least one light-generating source disposed on the substrate and coupled to the conductive traces; and

an interface at least partly covering the light-generating source on the substrate, the interface providing an effective heat transfer means to dissipate heat generated by the light-generating source so that the illuminator can safely contact the skin of a patient.

13. The illuminator of claim 12, wherein the illuminator is sufficiently lightweight to be worn against the skin of a newborn infant without injury.

14. The illuminator of claim 12, wherein the illuminator is flexible and adapted to conform to the skin of the patient.

15. The illuminator of claim 12, wherein the interface defines spaces between the covering and the substrate.

16. The illuminator of claim 15, wherein the spaces comprise channels for convective heat transfer.

17. The illuminator of claim 15, wherein there are a plurality of the light-generating sources, and the spaces are directly adjacent the light-generating sources.

18. The illuminator of claim 15, wherein the spaces are in communication with apertures provided through the substrate.

19. The illuminator of claim 12, wherein the interface comprises a insulating layer.

20. The illuminator of claim 12, further including means for passively cooling the light-generating source.

21. The illuminator of claim 12, further including means for active cooling of the light-generating source.

22. The illuminator of claim 12, wherein the illuminator defines a skin-contacting surface, the light-generating source has an intensity in excess of 50 microwatts, and the interface limits the maximum temperature of the skin-contacting surface to about 110°F.

23. The illuminator of claim 12, wherein the interface comprises a flexible, polymeric layer permitting light energy to penetrate therethrough and conforming to the skin of a patient.

24. An illuminator for delivering light energy to the skin for phototherapy, the illuminator comprising:

a thin, lightweight substrate;

a plurality of conductive traces affixed to the substrate and being adapted to connect to an electrical power source;

at least two discrete light sources disposed on the substrate and coupled to the conductive traces; and

an interface at least partly covering the light-generating sources on the substrate, the interface diffusing the light emitted from the discrete light sources, the illuminator being adapted to contact the skin of a patient.

25. The illuminator of claim 24, wherein the illuminator is sufficiently lightweight to be worn against the skin of a newborn infant without injury.

26. The illuminator of claim 24, wherein the interface comprises at least one material effective to diffuse light energy from the light source.

27. The illuminator of claim 24, wherein the interface comprises a blend of materials having different refractive indices.

28. The illuminator of claim 24, wherein the interface has an exterior surface adapted to contact the skin of a patient, the exterior surface being irregular to diffuse the light emitted from the discrete light sources.

29. The illuminator of claim 24, wherein the light sources are LEDs.

30. The illuminator of claim 24, further including a reflective backing in intimate contact with the substrate and comprising a heat conducting material.

31. The illuminator of claim 24, wherein the substrate comprises a print circuit board.

32. The illuminator of claim 44, further including a reflector for reflecting light from the light sources away from the substrate.

33. A wearable phototherapeutic illuminator for delivering light energy to the skin of a patient, comprising:

a flexible substrate;

at least one light-generating source disposed on the substrate; and

a flexible, polymeric layer covering the light-generating source, the layer permitting light energy to penetrate therethrough and adapted to substantially conform

to the skin of a patient.

34. The illuminator of claim 33, wherein the illuminator is sufficiently lightweight to be worn against the skin of a newborn infant without injury.

35. The illuminator of claim 33, wherein there are a plurality of the light-generating sources, the layer comprising a transparent matrix with glass bubbles dispersed therethrough to diffuse the light emitted from the light-generating sources.

36. The illuminator of claim 33, wherein there are a plurality of the light-generating sources, the layer comprising a blend of materials having different refractive indices to diffuse the light emitted from the light-generating sources.

37. The illuminator of claim 33, wherein there are a plurality of the light-generating sources, the layer having an exterior surface adapted to contact the skin of a patient, the exterior surface being irregular to diffuse the light emitted from the light-generating sources.

AMENDED CLAIMS

[received by the International Bureau on 26 December 2000 (26.12.00);
original claims 1 – 37 replaced by amended claims 1 – 36 (6 pages)]

WHAT IS CLAIMED IS:

1. An illuminator for delivering light energy to the skin of a patient for phototherapy, the illuminator comprising:

5 a thin, lightweight flexible substrate;
 a plurality of conductive traces affixed to the substrate and being adapted to connect to an electrical power source;

10 at least one discrete light-generating source disposed on the substrate and coupled to the conductive traces;

 a reflector located on the substrate for reflecting light from the at least one light-generating source toward the patient; and

15 a covering at least partly surrounding the substrate and having an exterior surface that is spaced apart from the light-generating source, the exterior surface being adapted to contact the skin of a patient.

20 2. The illuminator of claim 1, wherein the illuminator is structured to be placed in contact with the skin of a newborn infant and used without injury.

25 3. The illuminator of claim 1, which includes a plurality of discrete light-generating sources disposed on the substrate and coupled to the conductive traces.

30 4. The illuminator of claim 1, wherein the illuminator is configured to facilitate the transfer of heat produced by the at least one light-generating source away from the skin of the patient sufficient to prevent such heat from adversely affecting the patient.

 5. The illuminator of claim 4, wherein the illuminator includes at least one fin positioned to provide increased transfer of heat produced by the

light-generating sources away from the skin of the patient relative to a substantially identical illuminator without the fin.

5 6. The illuminator of claim 4, wherein the covering is spaced apart from the substrate and further comprising at least one cavity between the covering and the substrate.

10 7. The illuminator of claim 1, wherein the covering at least partly defines an internal structure adapted to facilitate at least one of a) dissipation of heat produced by the light-generating sources away from the skin of the patient, and b) diffusion of light generally toward the skin of the patient.

15 8. The illuminator of claim 7, wherein the internal structure is adapted to both a) dissipate heat produced by the light-generating sources away from the skin of the patient, and b) diffuse light generally toward the skin of the patient.

20 9. The illuminator of claim 1, wherein the light-generating source comprises an LED, and the reflector comprises a thin, flexible sheet perforated with holes through which the LED projects.

25 10. The illuminator of claim 1, further including cooling means for transferring heat generated by the at least one light-generating source so that the illuminator can safely and comfortably contact the skin of a patient.

30 11. The illuminator of claim 1, wherein the exterior surface is defined by a disposable overwrap sized to at least partly cover the illuminator and provide a contamination barrier between the illuminator

and the skin of the patient.

12. An illuminator for delivering light energy to the skin of a patient for phototherapy, the illuminator comprising:

- 5 a thin, lightweight substrate;
- a plurality of conductive traces affixed to the substrate and being adapted to connect to an electrical power source;
- at least one light-generating source disposed
- 10 on the substrate and coupled to the conductive traces; and
- an interface at least partly covering the light-generating source on the substrate, the interface providing heat transfer means for
- 15 passively or actively cooling the light-generating source and transferring heat generated by the light-generating source so that the illuminator can safely contact the skin of a patient.

13. The illuminator of claim 12, wherein the

20 illuminator is flexible and adapted to conform to the skin of the patient.

14. The illuminator of claim 12, wherein the interface defines spaces between the covering and the substrate.

25 15. The illuminator of claim 14, wherein the spaces comprise channels for convective heat transfer.

16. The illuminator of claim 15, wherein the heat transfer means actively cools the at least one light-generating source by convection using the channels.

30 17. The illuminator of claim 14, wherein there are a plurality of the light-generating sources, and the

spaces are adjacent to the light-generating sources.

18. The illuminator of claim 14, wherein the spaces are in communication with apertures provided through the external surface of the illuminator.

5 19. The illuminator of claim 12, wherein the interface comprises a thermal insulating layer.

20. The illuminator of claim 12, further including diffusing means for diffusing light emitted from the at least one light-generating source.

10 22. The illuminator of claim 12, wherein the interface comprises a flexible, polymeric layer permitting light energy to penetrate therethrough and conforming to the skin of a patient.

15 23. An illuminator for delivering light energy to the skin for phototherapy, the illuminator comprising:

 a thin, lightweight substrate;

 a plurality of conductive traces affixed to the substrate and being adapted to connect to an electrical power source;

20 at least one discrete light-generating source disposed on the substrate and coupled to the conductive traces; and

 an interface at least partly covering the light-generating source on the substrate, the interface comprises a combination of at least two materials having different refractive indices so as to diffuse the light emitted from the discrete light-generating source, the illuminator being adapted to contact the skin of a patient.

30

24. The illuminator of claim 23, wherein the interface has an exterior surface adapted to contact the

skin of a patient, the exterior surface having surface deformities to diffuse the light emitted from the at least one discrete light-generating source.

5 25. The illuminator of claim 23, wherein the interface further provides heat transfer means for passively or actively cooling the light-generating source and transferring heat generated by the light-generating source so that the illuminator can safely
10 contact the skin of a patient.

 26. The illuminator of claim 23, further including a reflector for reflecting light from the at least one discrete light-generating source toward the patient.

 27. The illuminator of claim 26, wherein the
15 reflector is a diffusive reflector.

 28. The illuminator of claim 27 wherein the diffusive reflector has a Lambertian (random) reflecting surface.

 29. The illuminator of claim 23, wherein the
20 interface has an exterior surface adapted to contact the skin of a patient, the exterior surface being irregular to diffuse the light emitted from the discrete light sources.

 30. The illuminator of claim 23, wherein the at
25 least one discrete light-generating source is an LED.

 31. The illuminator of claim 23, further including a reflective backing in intimate contact with the substrate and comprising a heat conducting material.

30 32. The illuminator of claim 23, wherein the substrate comprises a print circuit board.

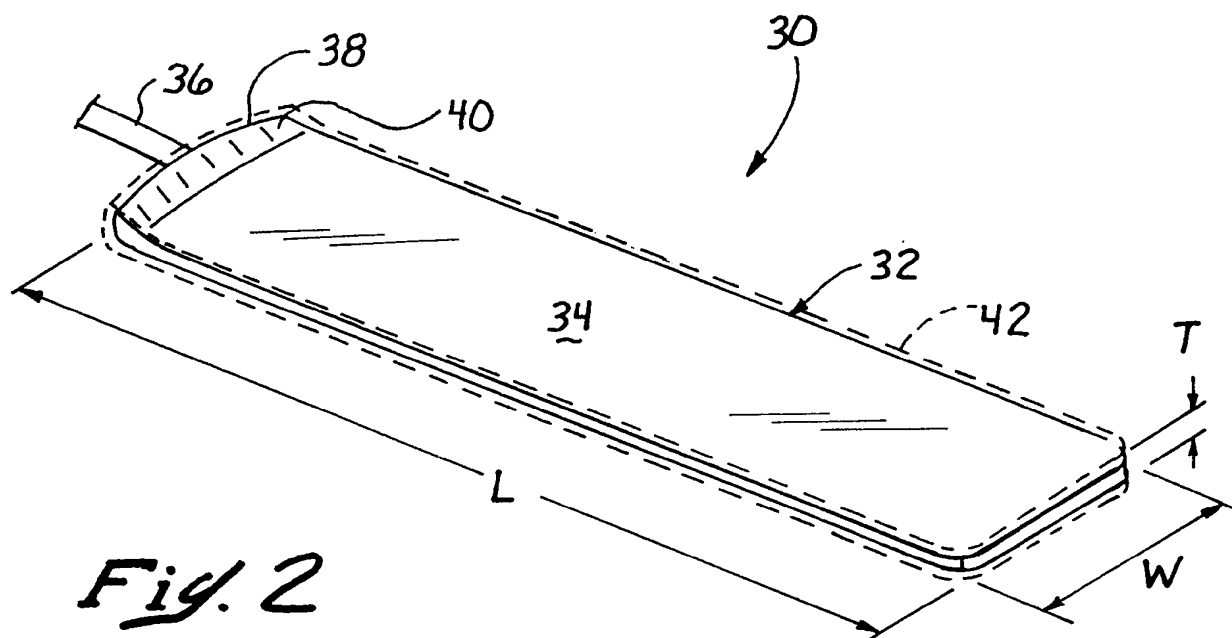
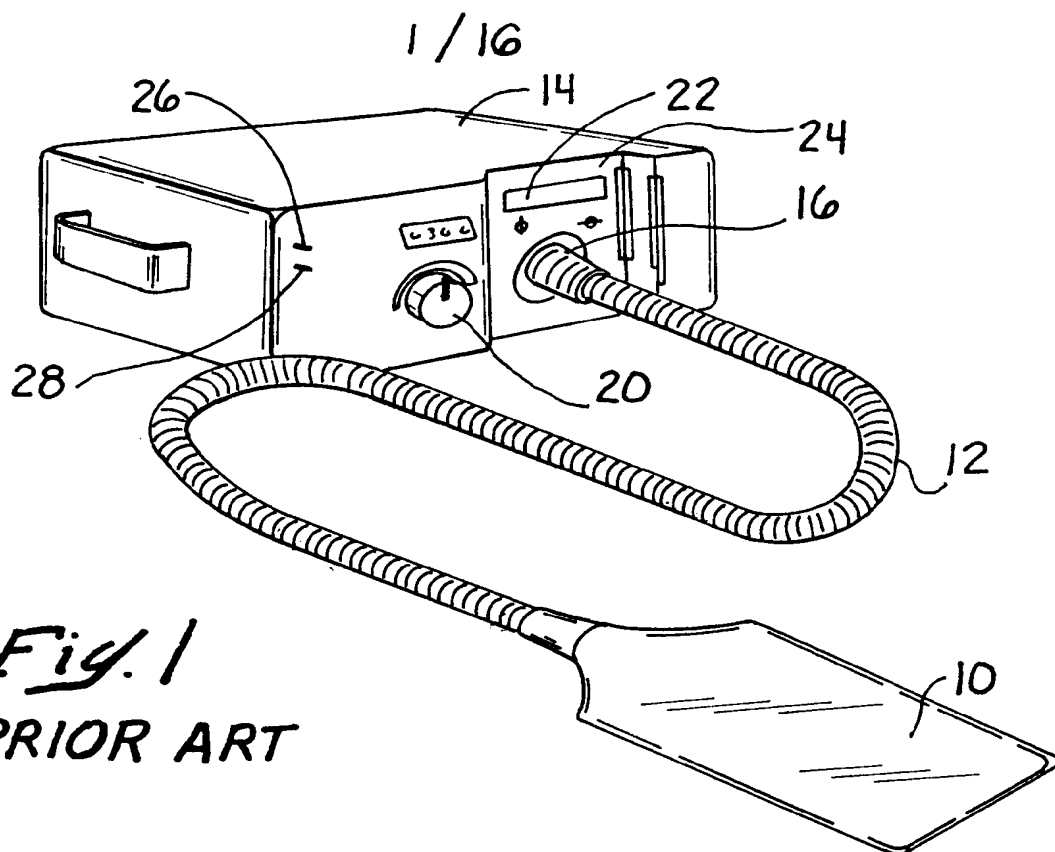
33. A wearable phototherapeutic illuminator for delivering light energy to the skin of a patient, comprising:

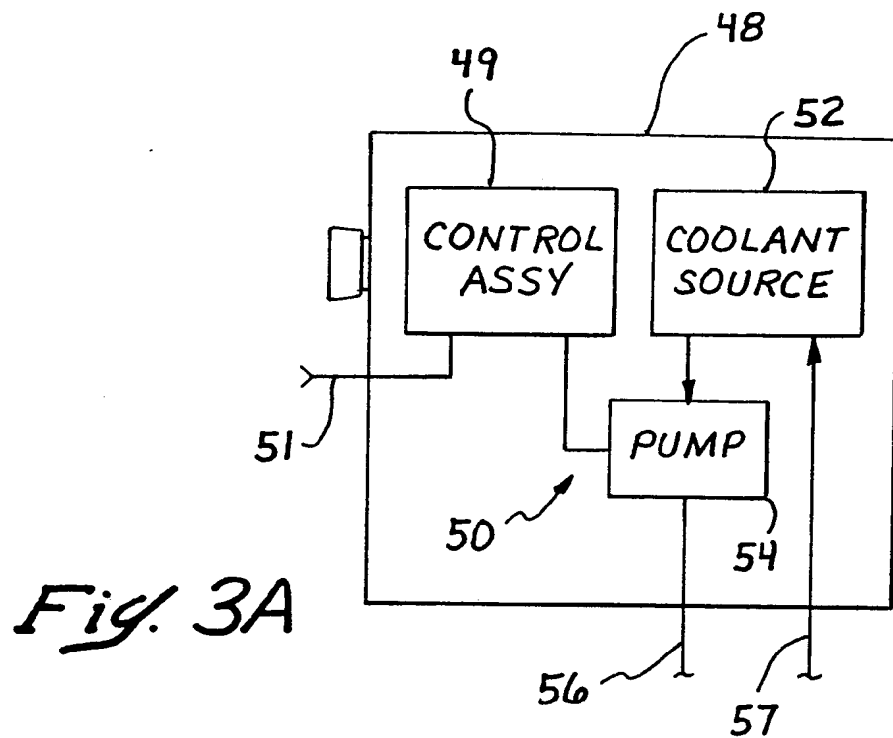
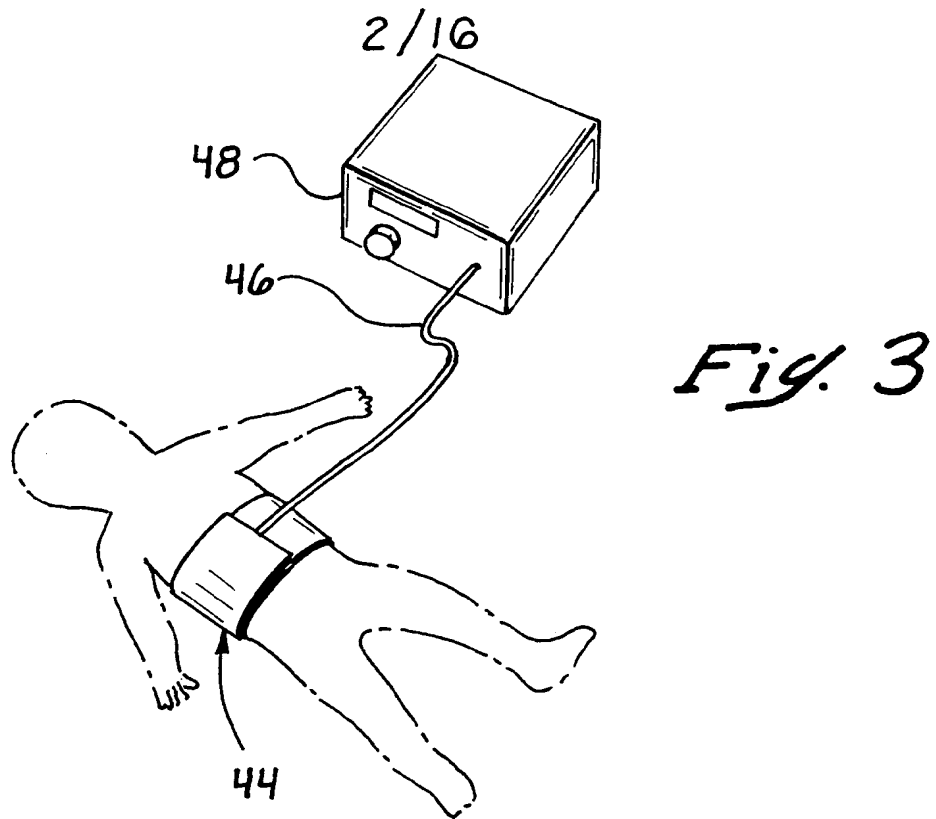
- a flexible substrate;
- 5 a plurality of light-generating sources disposed on the substrate; and
- a flexible, polymeric layer covering the light-generating sources, the layer permitting light energy to penetrate therethrough and adapted to substantially conform to the skin of a patient,
- 10 the layer diffusing the light emitted from the sources to result in a more uniform overall emittance, the illuminator being adapted to contact the skin of a patient.

15 34. The illuminator of claim 33, wherein the layer comprises a matrix with glass bubbles dispersed therein to diffuse the light emitted from the light-generating sources.

20 35. The illuminator of claim 33, wherein the layer comprises a matrix with titania dispersed therein to diffuse the light emitted from the light-generating sources.

25 36. The illuminator of claim 33, wherein the layer comprises an exterior surface adapted to contact the skin of the patient, the exterior surface having surface deformities to diffuse the light emitted from the light-generating sources.





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Fig. 4

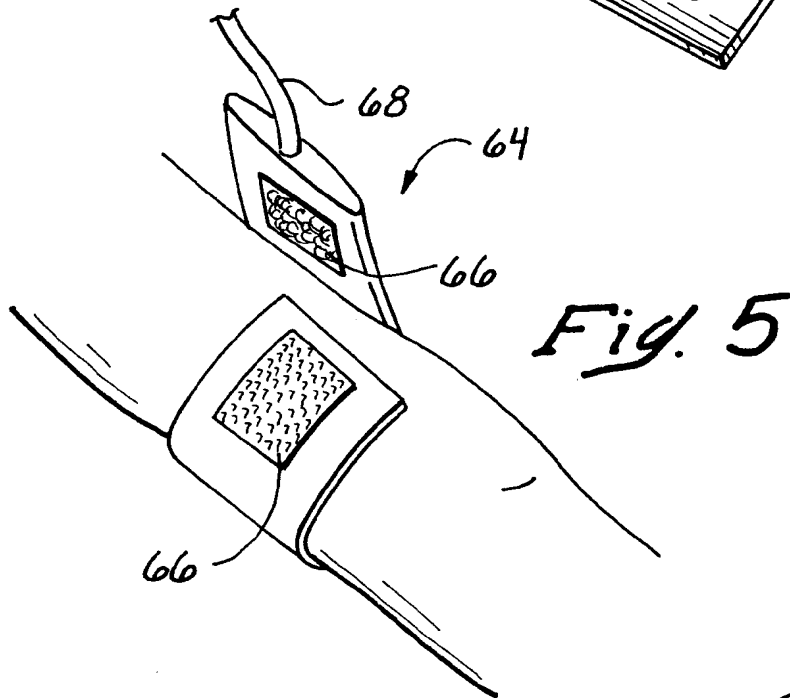
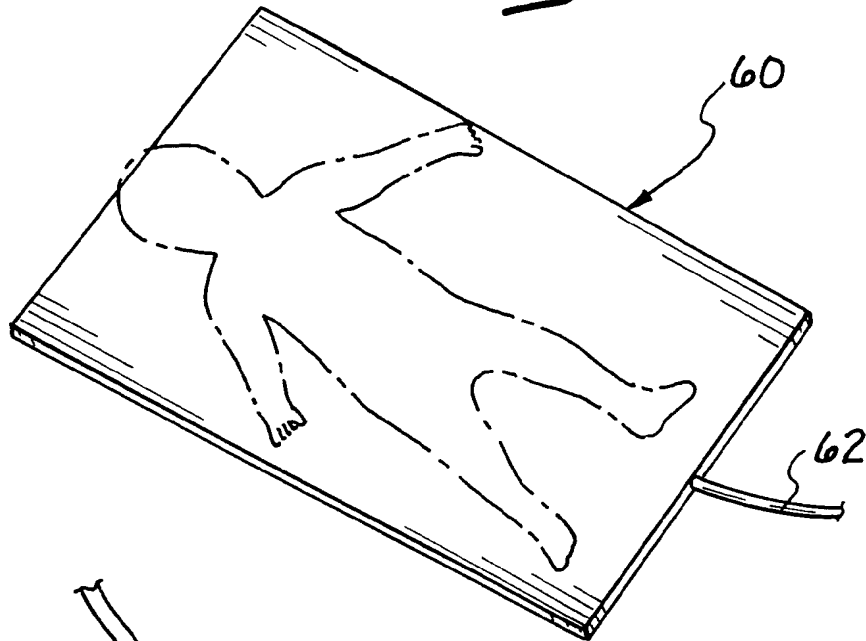
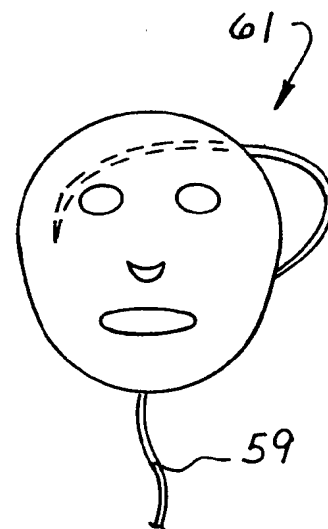
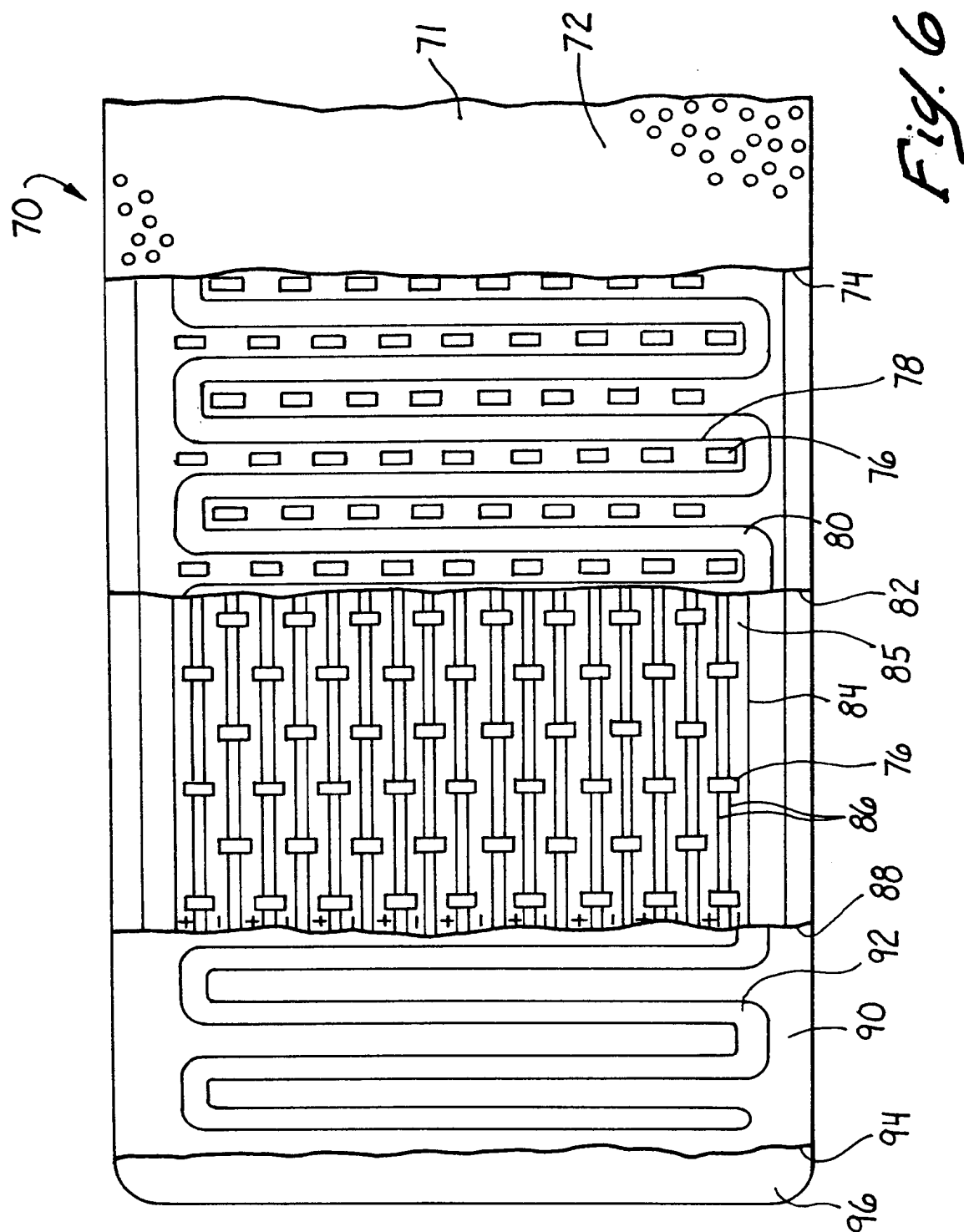


Fig. 5

Fig. 5A



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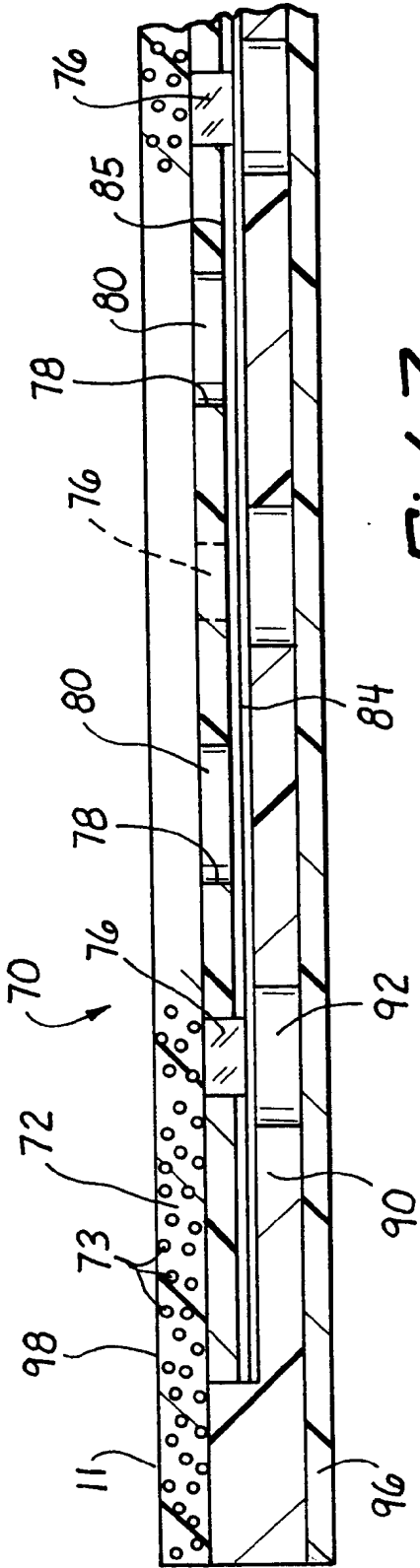


Fig. 7

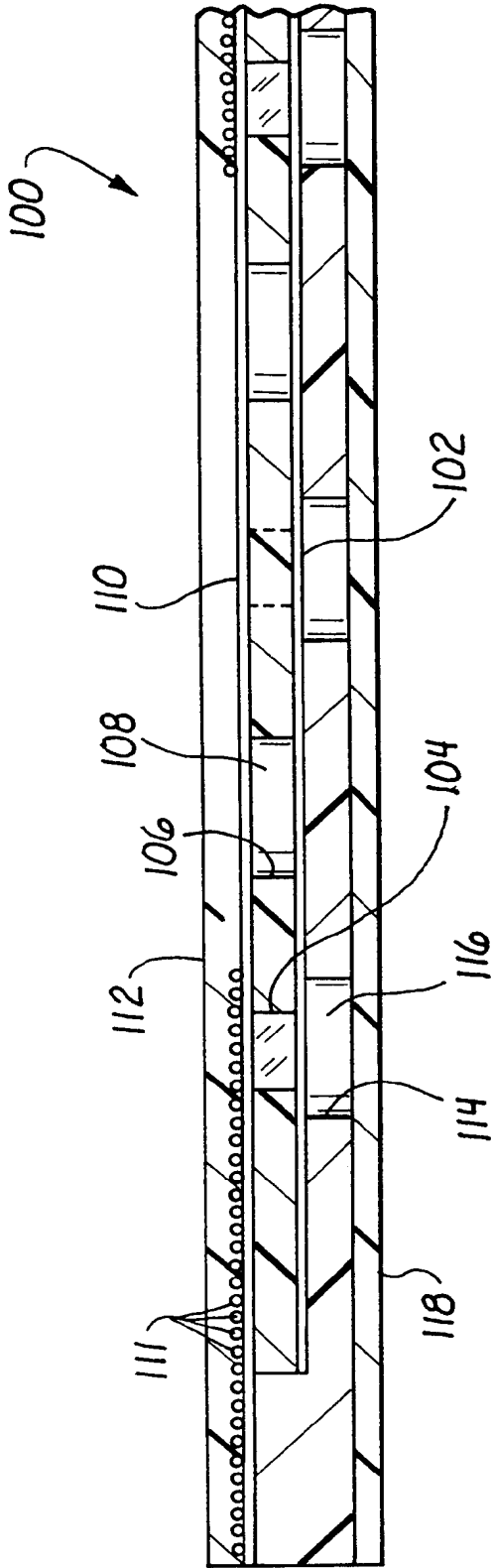
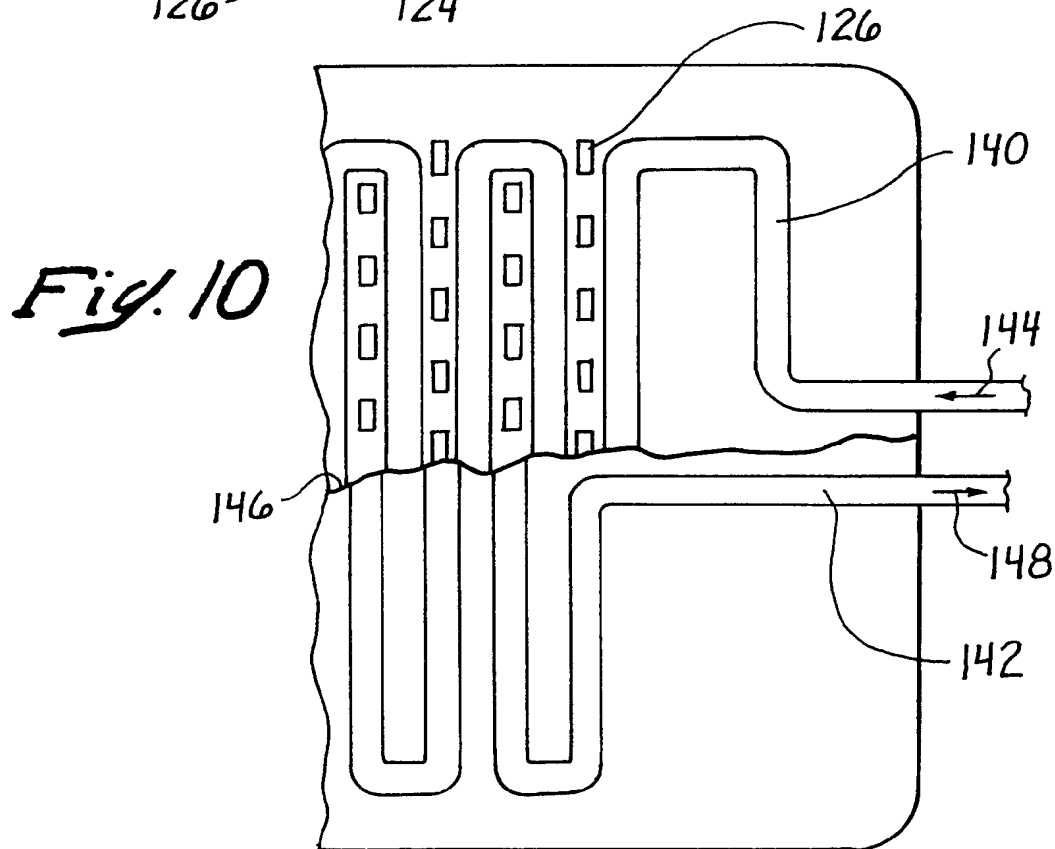
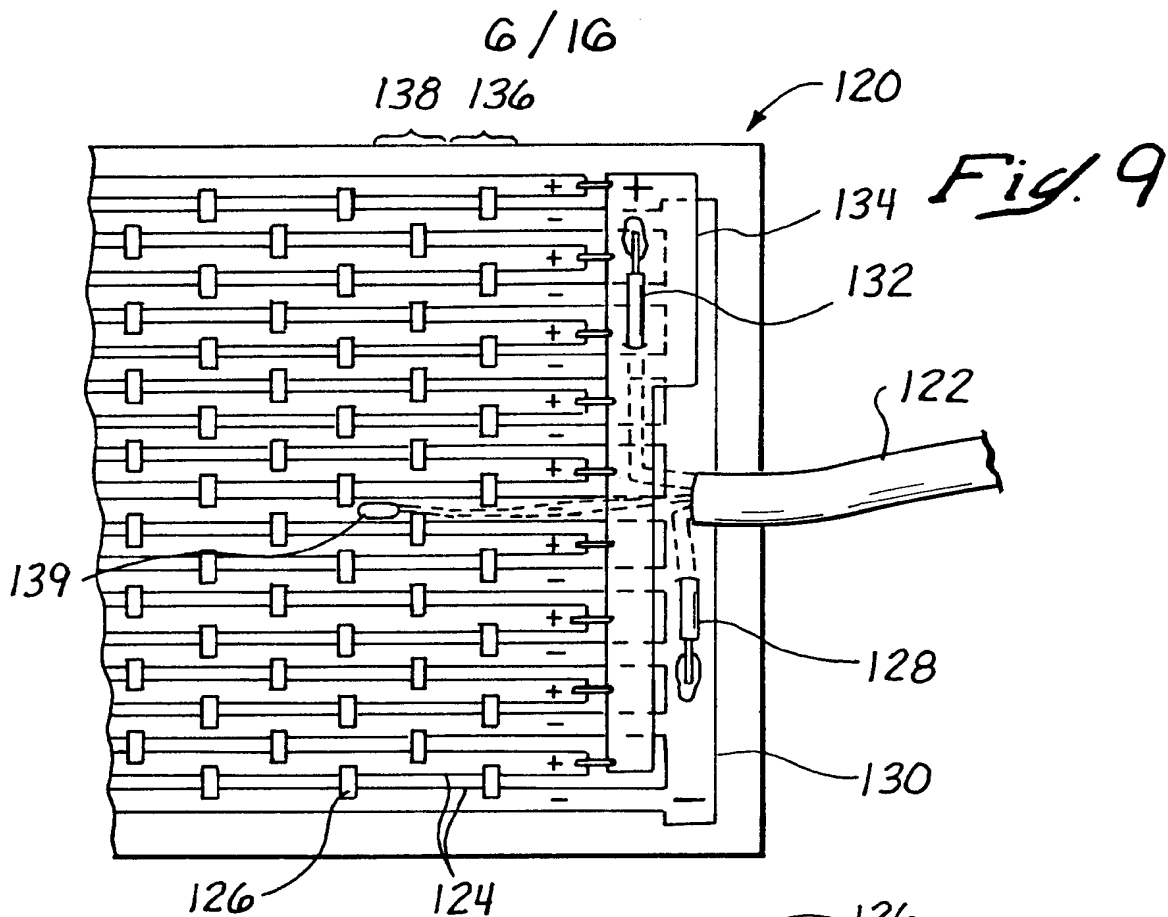


Fig. 8



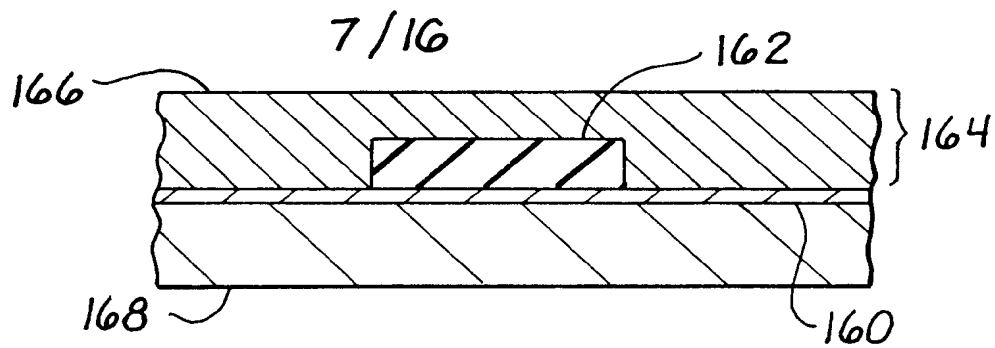


Fig. 11A

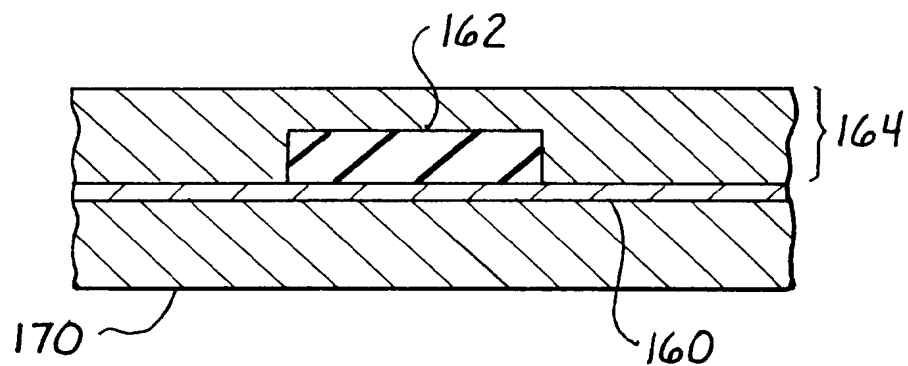


Fig. 11B

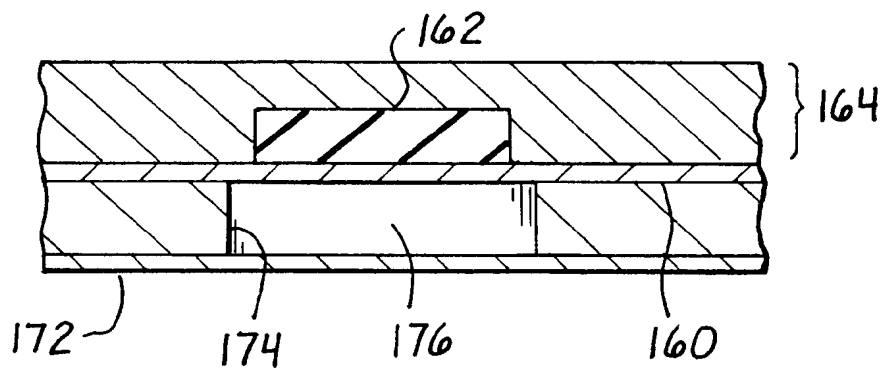


Fig. 11C

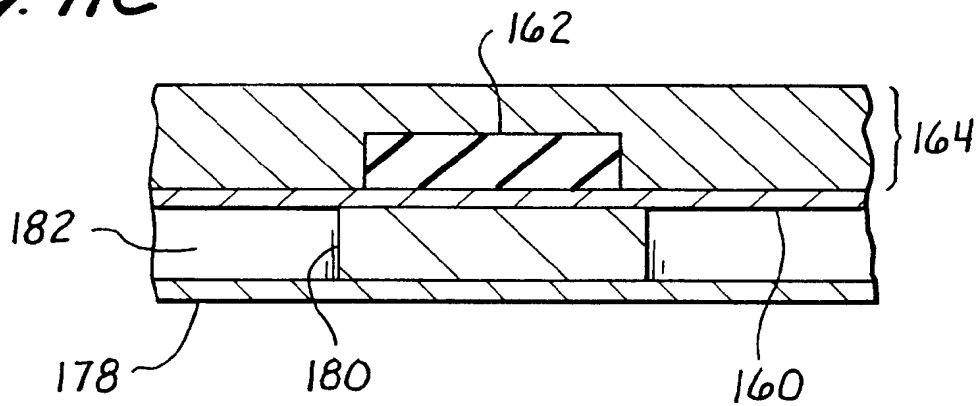


Fig. 11D

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Fig. 12A

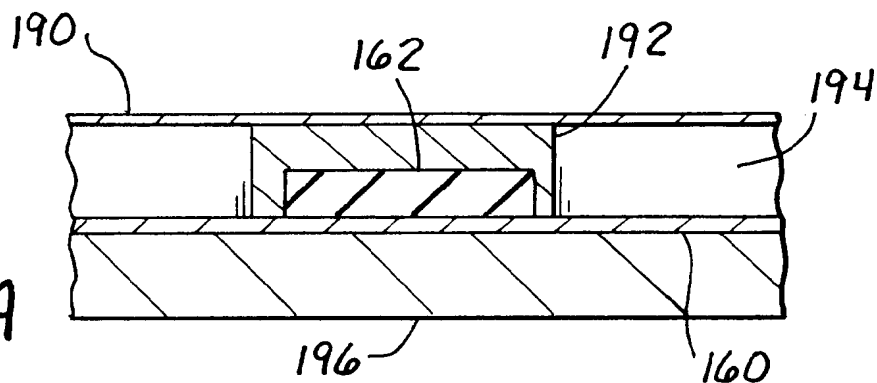


Fig. 12B

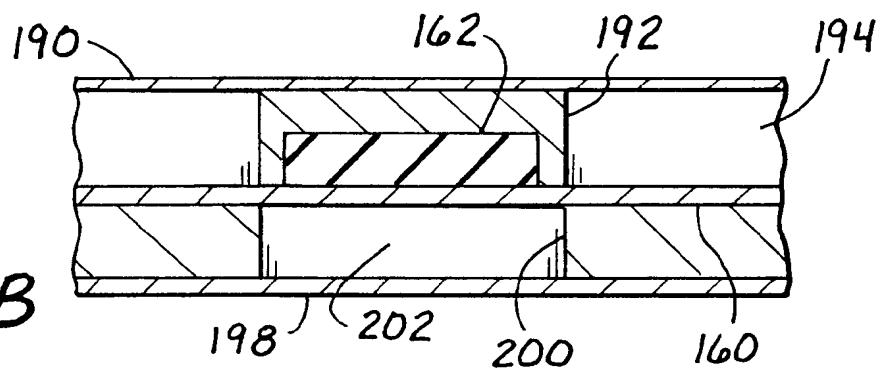


Fig. 12C

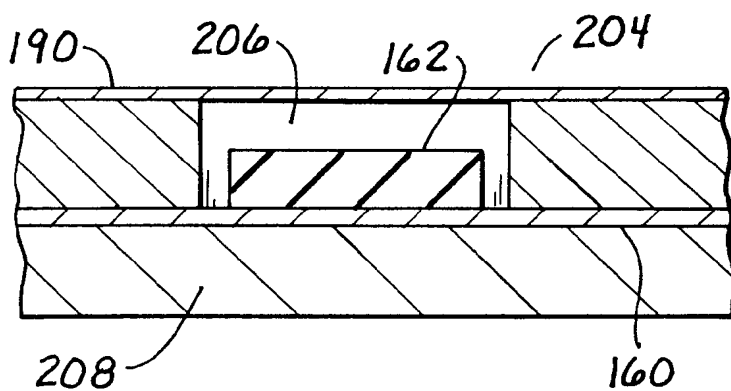
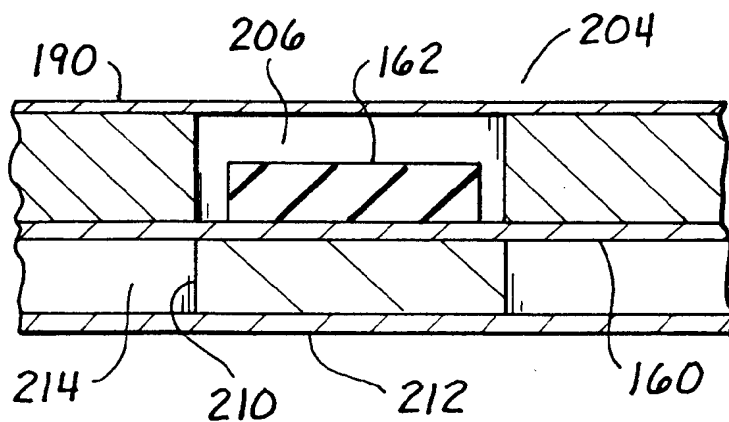
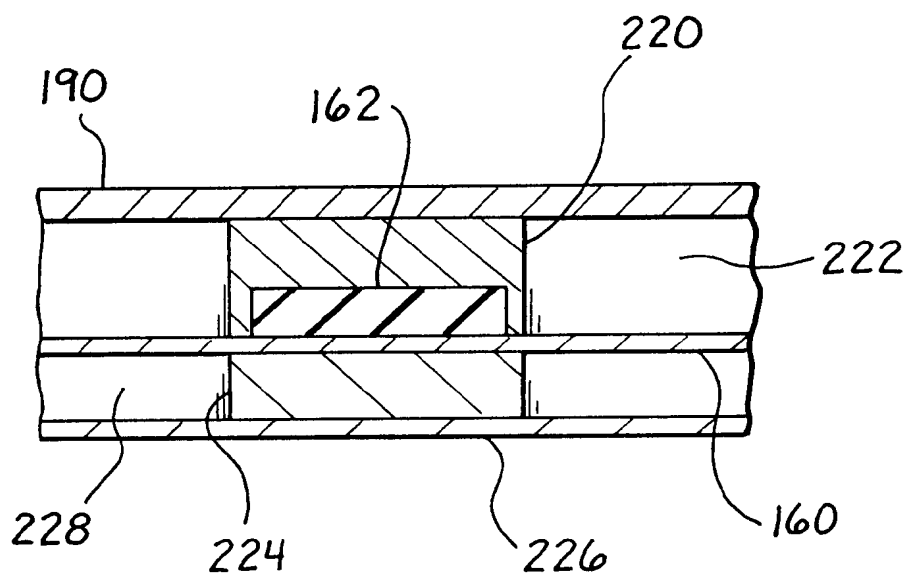
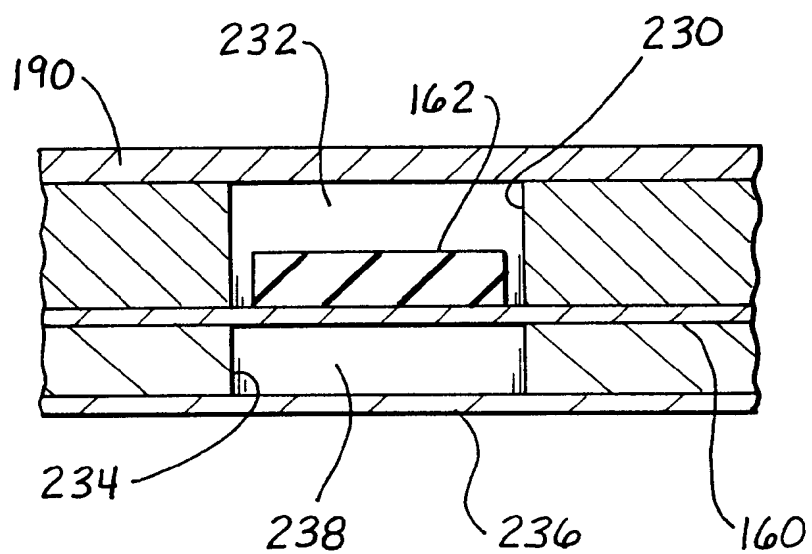
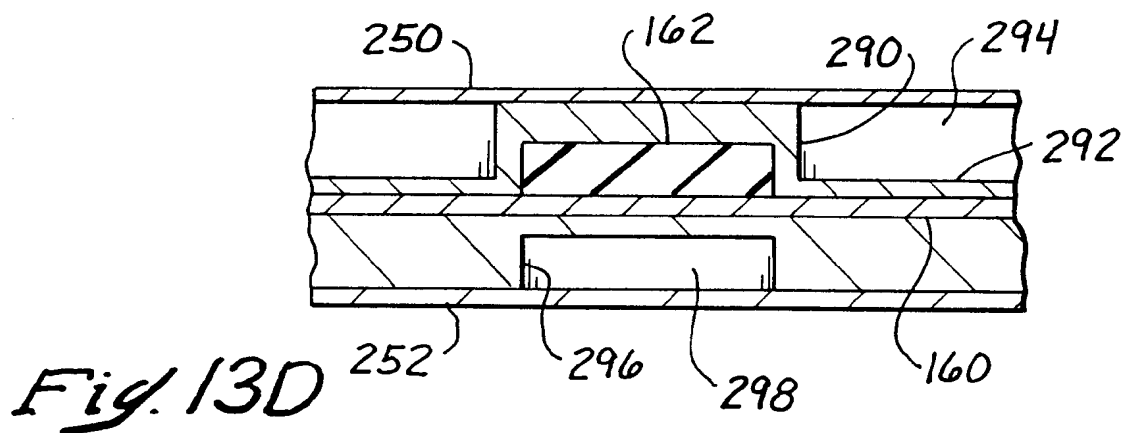
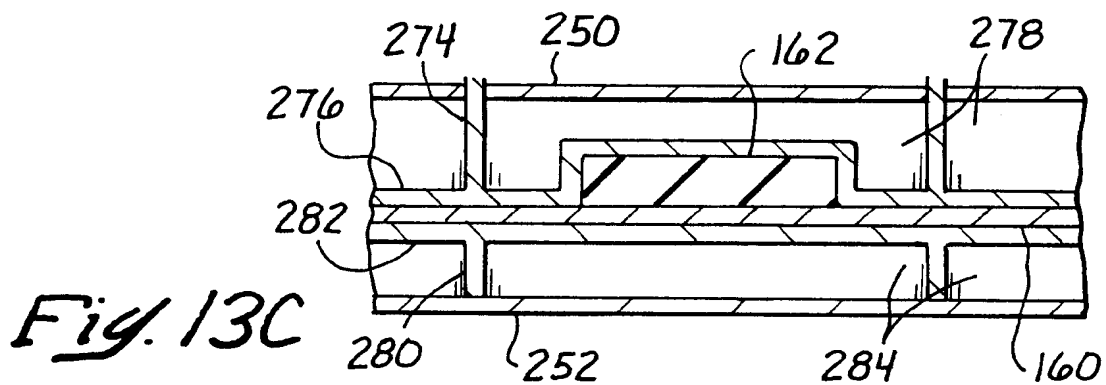
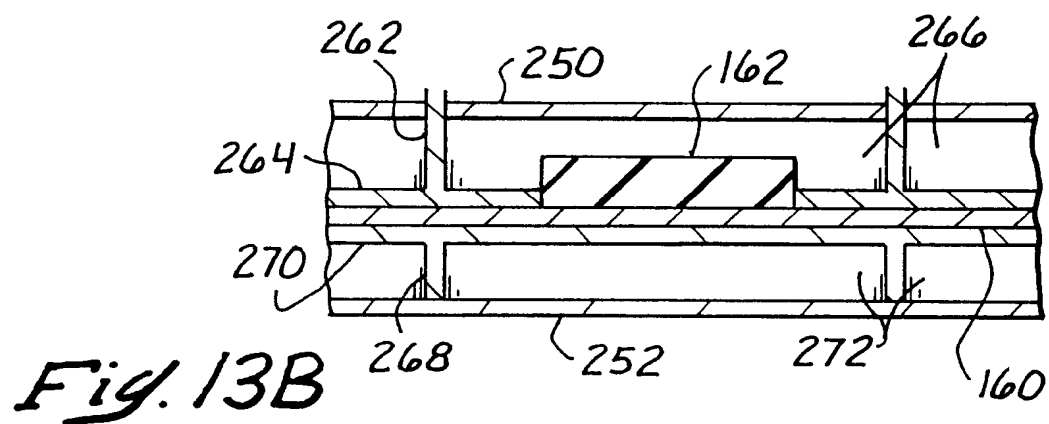
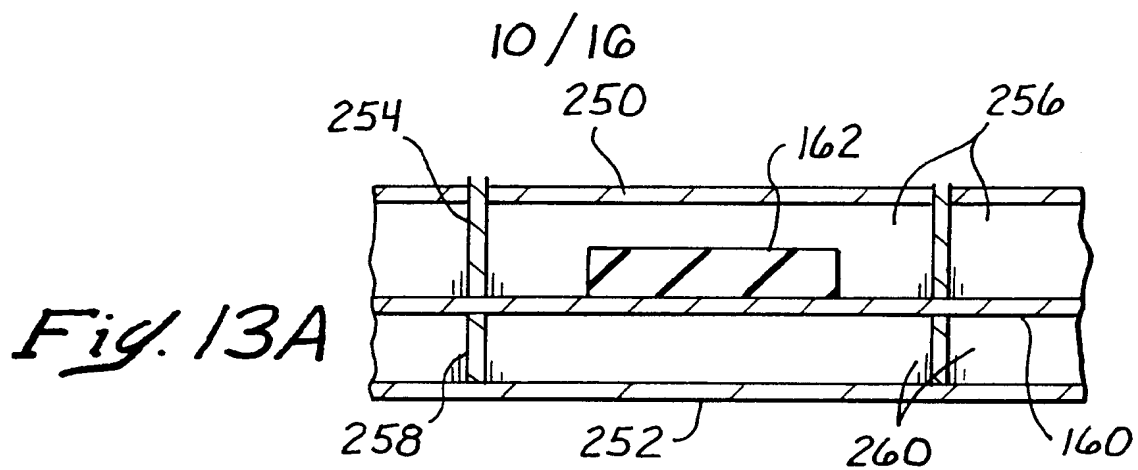


Fig. 12D



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*Fig. 12E**Fig. 12F*



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Fig. 14A

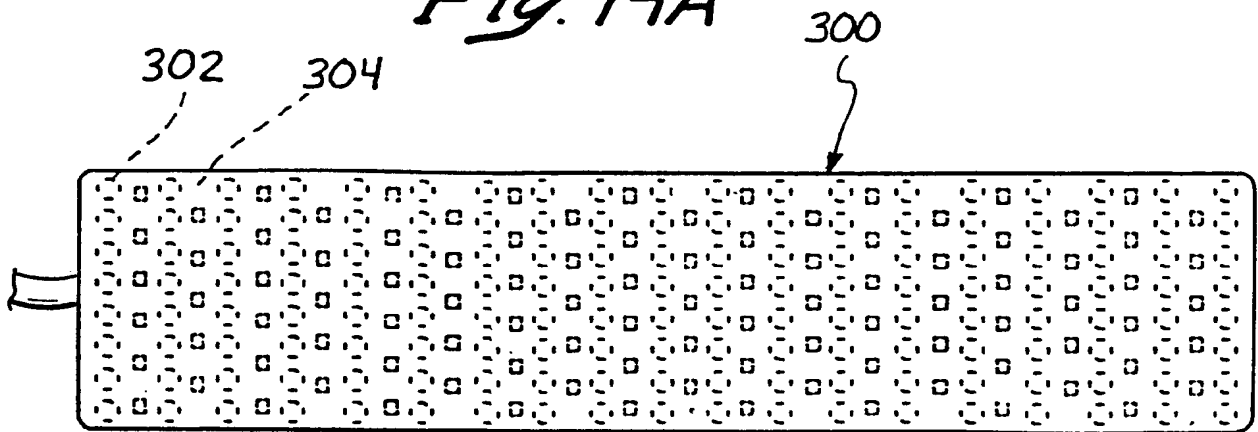


Fig. 14B

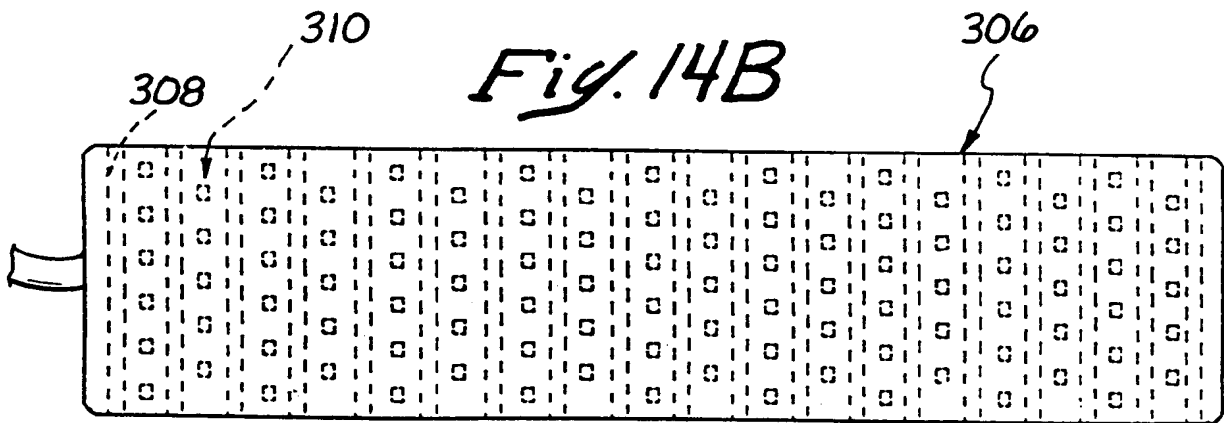
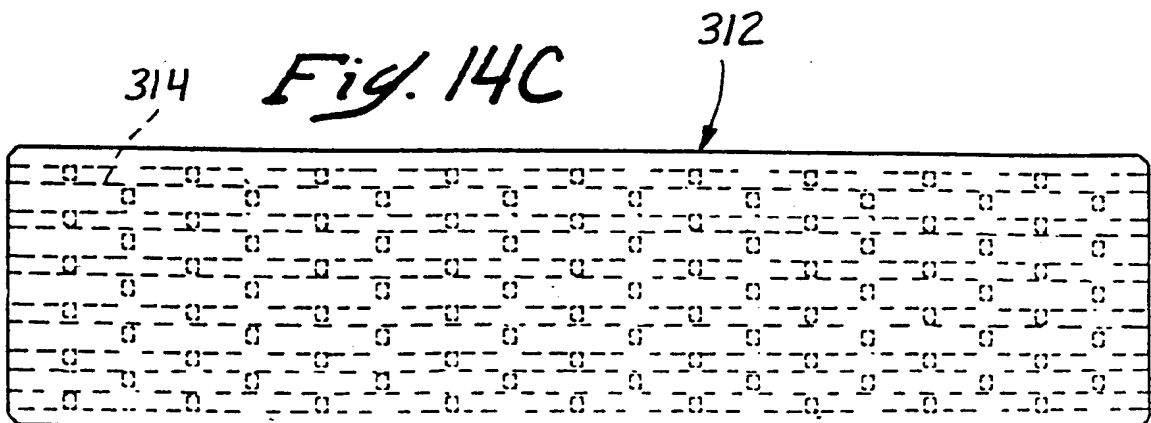


Fig. 14C



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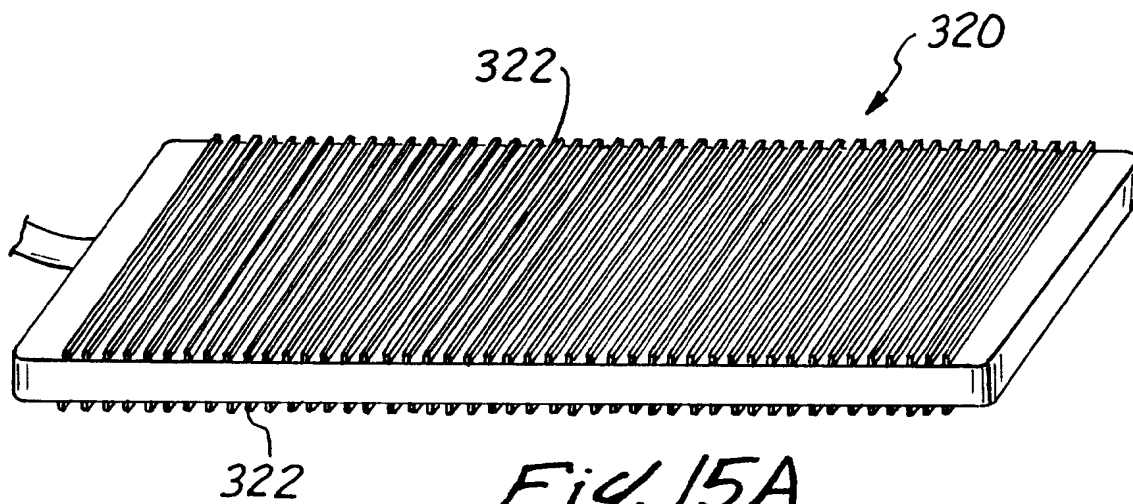


Fig. 15A

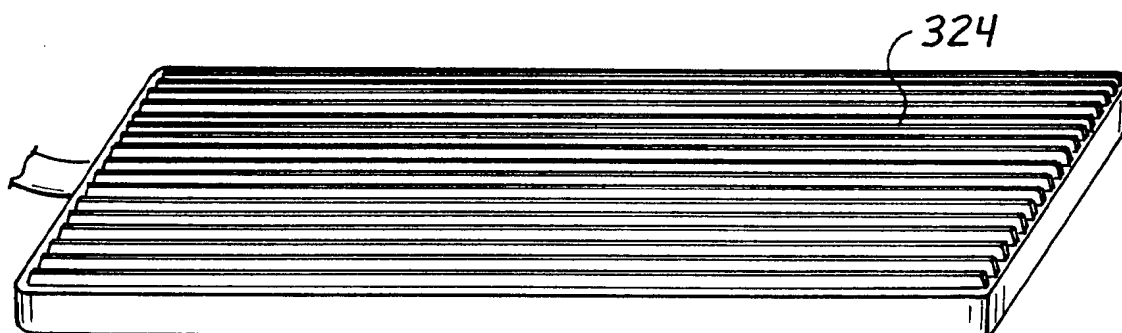
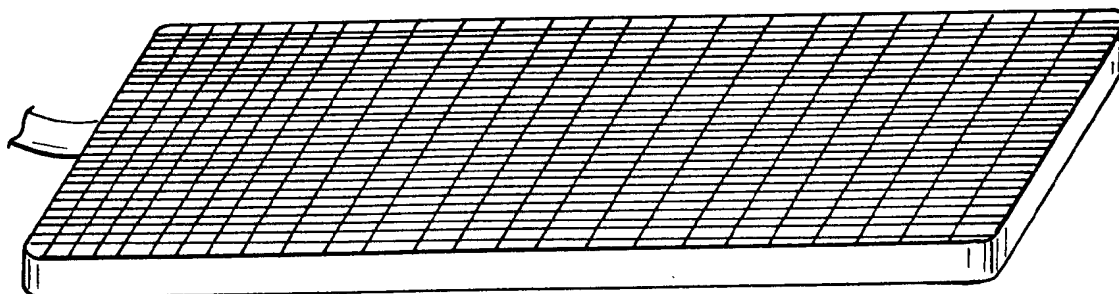
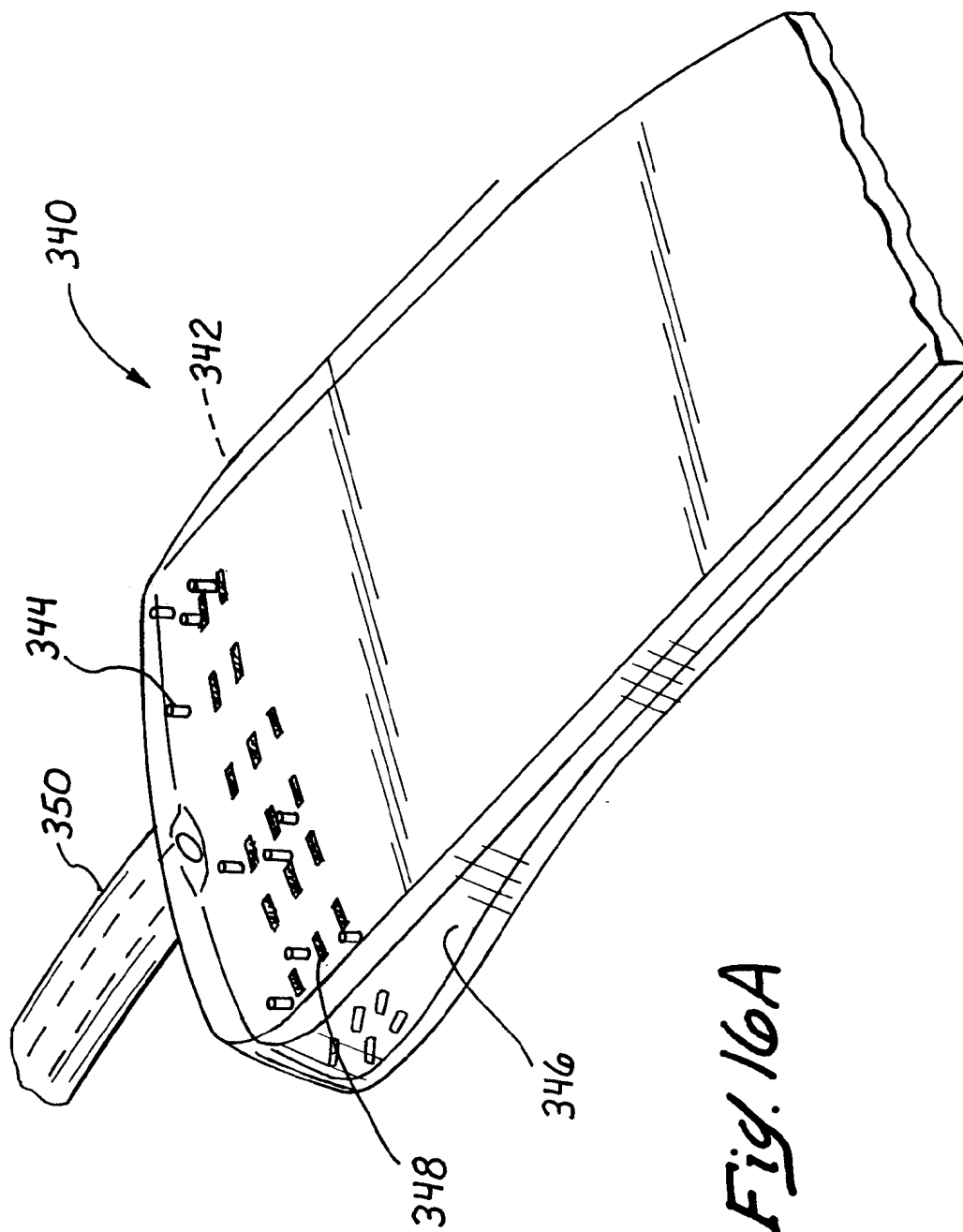


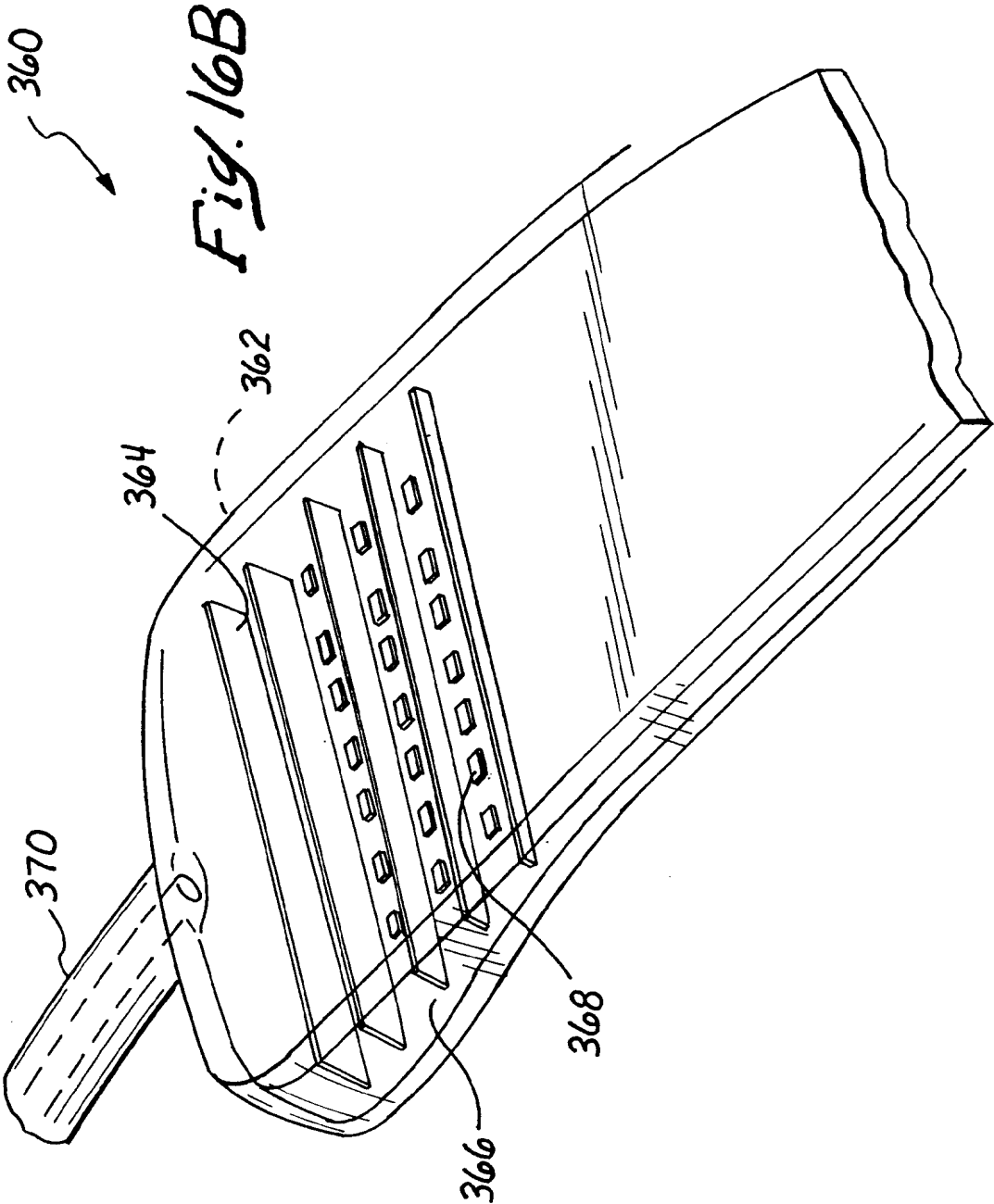
Fig. 15B

Fig. 15C

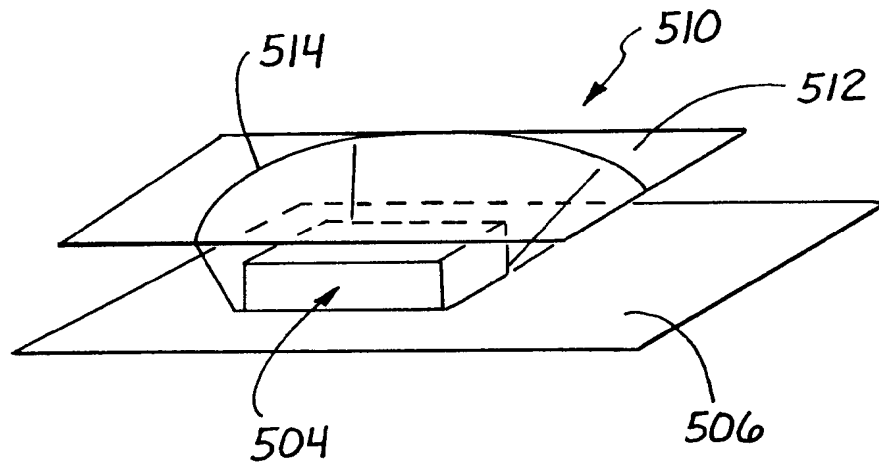
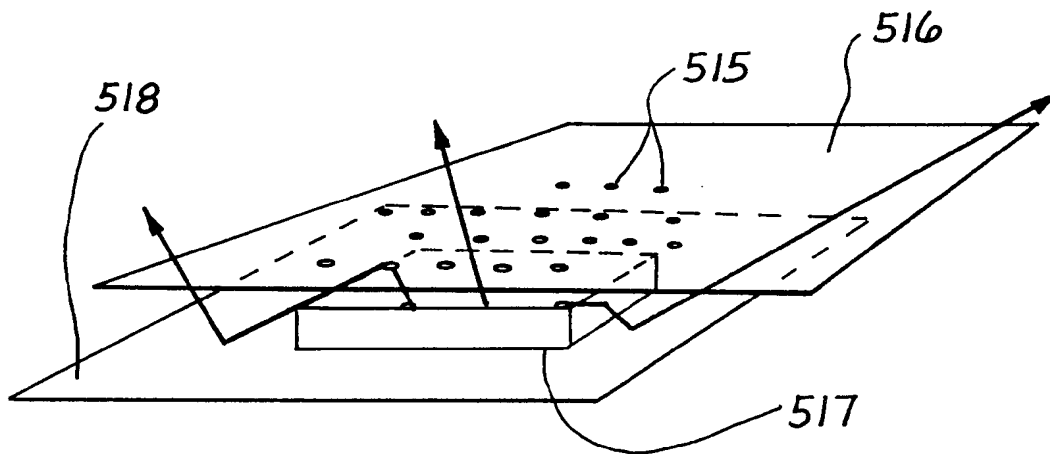


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*Fig. 17A**Fig. 17B*

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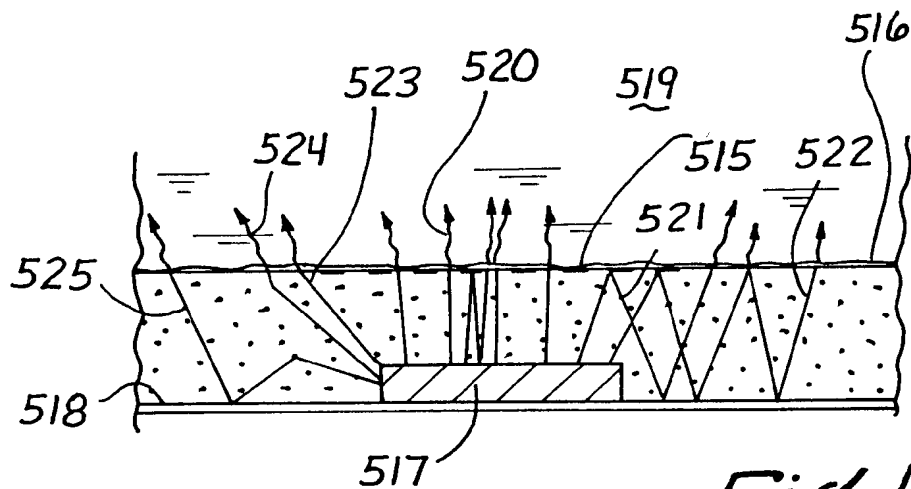


Fig. 17C

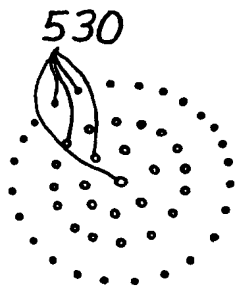


Fig. 18A

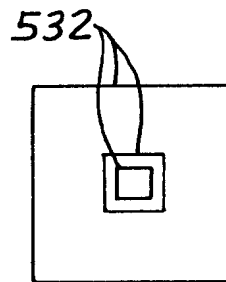


Fig. 18B

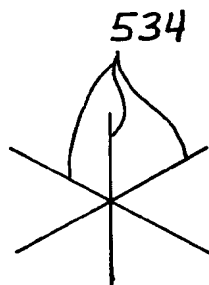


Fig. 18C

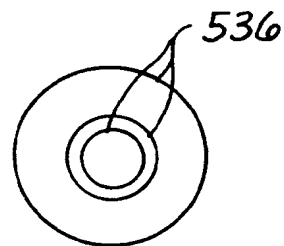


Fig. 18D

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US00/22720

A. CLASSIFICATION OF SUBJECT MATTER

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US CL : 606/9, 13; 607/88

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,616,140 A (PRESCOTT) 01 April 1997, entire document.	1-8, 11-19, 23-26, 28-34, 37
A	US 5,913,883 A (ALEXANDER et al.) 22 June 1999, entire document.	1-37
A	US 5,634,711 A (KENNEDY et al.) 03 June 1997, entire document.	1-37
A	US 5,800,479 A (THIBERG) 01 September 1998, entire document.	1-37

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

03 OCTOBER 2000

Date of mailing of the international search report

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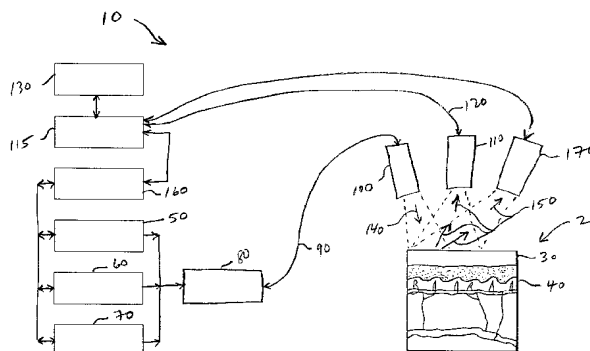
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(54) Title: **PHOTOSTIMULATON TREATMENT APPARATUS AND METHODS FOR USE**



(57) **Abstract:** A therapeutic treatment apparatus (10) for photostimulation of biological tissue (20, 30, 40) that includes at least one treatment radiation source source (50) configured to radiate energy at a predetermined wavelength selected from the range approximately between 400 and 1,500 nanometers and adapted to illuminate the biological tissue (20, 30, 40). The apparatus further incorporates an infrared camera (110) configured to detect infrared radiation and adapted to produce image signals corresponding to the detected radiation. A data processing and recording device (115) is also included that is capable of receiving and processing the image signals and is adapted to generate an electronic signal in the form of a plurality of frames corresponding to the image signals. The data processing and recording device (115) is also configured to capture and analyze the frames to quantify the radiation emitted by the biological tissue in units of measurement selected from the group including wavelength, radiance, luminosity, area, volume, temperature, change in temperature, rate of change of temperature, relative temperature, energy, change in energy, rate of change of energy, and relative energy. The data processing and recording device (110) is also configured to detect, block, and/or subtract the energy emitted from the radiation source (50) that is reflected by the target (20, 30, 40) when quantifying the energy emitted by the biological tissue (20, 30, 40) sans the reflected energy. A method for using the device (10) is also described.

WO 01/78830 A2

PHOTOSTIMULATION TREATMENT APPARATUS AND METHODS FOR USE**Technical Field**

This invention relates to an apparatus for treating various biological tissues and biomedical conditions in mammals with a photostimulation device that is precisely controlled
5 using, in part, a high-precision temperature monitoring device such as a thermographic diagnostic device.

Background of the Invention

The treatment of various biomedical conditions in mammals have been treated by
10 physicians and therapists using a wide variety of photostimulation devices. Many such devices are configured to emit radiation having visible and infrared wavelengths (approximately between 400 to 11,500 nanometers) as it has been shown that therapeutic benefits may result from irradiating biological tissue with certain wavelengths of radiation for various periods of time. In various surgical applications, photostimulation devices are configured to emit radiation
15 outside the visible and near-infrared ranges described above to induce photoablation of various tissues, which, depending upon the type of resulting effect, is also referred to by those with skill in the art as ablation, vaporization, ionization, and destruction. In both surgical and therapeutic applications, various attempts have been made to monitor the temperature of the biological tissues subject to the incident radiation so that minimum and maximum energy input to the
20 biological tissues can be induced and/or maintained.

In any application of photostimulation techniques to biological tissue, various incident radiation parameters are to be selected, adjusted, and monitored including the wave length, energy, pulse duration (including a continuous pulse), divergence of the incident radiation beam, and luminosity. In the past, a wide variety of focusing and defocusing optics have been used to establish a quantified cross-sectional area of the incident radiation beam at the point along a beam axis that intersects the upper surface of the biological tissue. By selecting, monitoring, and controlling at least these parameters, then the user can control the effects on the target biological tissue from the incident radiation, which effects include thermal effects such as vaporization, ionization, heating by phonon absorption, and atomic and molecular electronic, rotational, and vibrational excitation.

In therapeutic applications, it is desirable to induce only so much energy of a selected wavelength on the biological tissue whereby certain desirable effects can be induced. These effects typically do not irradiate the target with enough energy to cause vaporization and/or ionization. However, in most therapeutic applications, the biological tissue is irradiated with enough energy to induce the desired therapeutic effect, which can include photocoagulation as well as less damaging thermal effects such as denaturing of the tissue proteins. Even less damaging effects can also be initiated that include photostimulated biochemical changes induced by electronic, rotational, and vibrational excitation of the various constituents of the target biological tissue. At least one study has attempted to classify the various optical properties of human tissue. See, e.g., p. 1386, Parrish, J.A., Deutsch, T. F., *Laser Photomedicine*, I.E.E.E. J. of Quantum Electronics, Vol. QE-20, No. 12, 12/1984; Meyer, R. A., et al., *A Laser Stimulator for the Study of Cutaneous Thermal and Pain Sensation*, I.E.E.E. Transactions on Biomedical Engineering, Vol. BME-23, No. 1, pp. 54-60, 1/1976; *A Brief Report, and Some Abstracts from the International Discussions of Laser Applications in*

Medicine, Paris, 7-8 July 1969, Medical and Biological Engineering, Vol. 8, pp. 427-430, Pergamon Press, 1970, Great Britain.

Various photostimulation devices have been taught in the prior art that are configured for irradiating and/or ablating target biological tissue. U.S. Pat. No. 5,346,488 to Prince et al. is limited to ablation of atherosclerotic plaque using short-duration laser pulses. U.S. Pat. Nos. 5,112,328; 5,196,004; 5,520,697; and 5,540,676 are directed to laser-based surgical devices that incorporate one or more laser radiation sources emitting electromagnetic radiation having one or more wavelengths and which are adapted to be used in various photomedicinal applications. U.S. Pat. No. 5,150,704 is directed to a device that incorporates multiple radiation sources for irradiating selected body parts with a plurality of laser probes. U.S. Pat. Nos. 4,854,320 and 5,002,051 are both limited to irradiation of laser energy to cause the denaturing of collagenous proteins of biological tissue to produce a biological glue to purportedly improves healing of wounds. Other examples of laser-based photostimulation devices configured for use in a variety of surgical and therapeutic applications include U.S. Pat. Nos. 4,573,465; 4,966,144; 5,161,526; 5,409,482; 5,445,146; 5,527,350; and 5,951,596; French Pat. Nos. 2,458,272; 2,561,515; 2,577,425; German Pat. Nos. 2,820,908; 3,401,492; and U.S.S.R. Pat Nos. 871,802; 1,242,187; 1,771,762; and 1,782,617.

None of these references disclose, teach, suggest, or provide any motivation for incorporating energy management devices that can precisely measure the actual amount of energy absorbed by the target biological tissue. In the applications described in the prior art where certain predetermined dosages of energy were to be applied to the target biological tissue, the radiation source and the method of its use to irradiate the target biological tissue was preconfigured to operate at a preselected wavelength, energy output, pulse rate, frequency, and/or exposure time.

Various types of temperature measuring devices exist. However, very few of the temperature measurement devices available in the prior art are suitable for use for purposes of the present invention. The prior art describes various types of temperature measurement devices. In most applications, surface contact thermistors and/or thermometers are used to measure the surface temperature of the target biological tissue. However, these types of devices are unsuitable for purposes of the present invention because they cannot be moved in real-time in applications where the target biological tissue includes a wide area that is irradiated in sections that are changed or rotated over some time interval. Additionally, the presence of a contact temperature measurement can interfere with the desired irradiation treatment modality.

U.S. Pat. Nos. 5,115,815; 5,386,117; 5,458,418; 5,467,126; 5,595,444; and 5,637,871 disclose various non-contact devices that are configured to measure the temperature of a target surface using various types of infrared radiation detection devices that operate using well-known thermography principles. Despite the capabilities of the various systems disclosed in the prior art, none the references discloses, suggests, or describes any motivation to use the thermography devices in accordance with the aspects of the present invention.

What has been needed but unavailable in the prior art is the accurate, real-time detection of temperature during treatment of a target biological tissue using surgical and therapeutic photostimulation devices. In particular, what has been needed is a photostimulation device and method for use that can impart a precisely controlled amount of energy to a target biological tissue and that can simultaneously, continuously, and precisely monitor the energy imparted to the target tissue. Accordingly, the present invention discloses an apparatus and a method for use that incorporates these and other capabilities.

SUMMARY OF THE INVENTION

In general, the present invention relates to an apparatus, and a method for using it, that is directed to the photostimulation of biological tissue such as, for example without limitation, cutaneous and subcutaneous biological tissues. Many types of electromagnetic radiation sources, guides, projectors, detectors, and controllers are available that are suitable for purposes of the present invention. The apparatus includes a therapeutic treatment apparatus for photostimulation of biological tissue that includes at least one treatment radiation source that is configured to emit radiation at a predetermined wavelength selected from the range of approximately between 400 and 11,500 nanometers.

The treatment radiation source may be one of a plurality of sources each configured to emit radiation at one or more wavelengths including, for purposes of illustration but not limitation, the above described range. In configurations where more than one treatment radiation source is used, then the sources are preferably coupled to an optical coupler. The coupler is further coupled to a radiation guide such as a fiber optic guide adapted to communicate the radiation of the treatment source or sources.

Preferably, the at least one treatment radiation source is selected from the group including semiconductor laser diodes, super-luminous diodes, light emitting devices, and solid-state laser diodes ("SSD"). More preferably, the at least one treatment radiation source is configured to emit radiation having a wavelength of approximately between 800 and 1,100 nanometers. Even more preferably, the at least one treatment radiation source is a neodymium-yttrium-aluminum-garnet ("Nd:YAG") laser tuned to emit radiation having a wavelength of approximately 1,064 nanometers.

The fiber optic guide may be further connected to a radiation focusing device such as a radiation emitting probe or wand that can be manipulated by a user for purposes of irradiating the target biological tissue. Each of the treatment radiation sources may

alternatively be coupled to additional, independent wands or probes via additional, separate fiber optic cables.

For configurations of the present that employ treatment radiation that is invisible to the unaided human eye, an additional radiation source configured to emit radiation in the visible spectrum may be coupled to the previous treatment radiation sources to operate as an aiming radiation source. Alternatively, the aiming radiation source may be coupled to each of the radiation sources that are independently coupled to separate wands or probes. In other variations, additional aiming radiation sources may be used to emit radiation at various visible wavelengths of light so that multiple aiming radiation wavelengths may be employed and coupled to selected treatment radiation sources. For example, visible blue light may indicate treatment radiation of a first wavelength, while visible red light may be used to indicate a different treatment radiation wavelength, and other colors may be used to indicate other types of treatment radiation. Alternatively, multiple different wavelengths of aiming radiation may be used to indicate modes of operation. For example, power settings below a certain predetermined threshold may be identified by visible red light, while higher power settings may be indicated using visible blue light.

The present invention also incorporates a video-type camera that is preferably configured to detect infrared radiation having a wavelength approximately between 700 and 20,000 nanometers. The camera is further preferably adapted to produce image signals corresponding to the detected radiation. A data processing and recording device is also included in the present invention, which is capable of receiving and processing the image signals and adapted to generate an electronic signal in the form of a plurality of digitally encoded frames corresponding to the image signals. The data processing and recording device preferably captures and analyzes the frames. In analyzing the frames, the data processing and recording device is configured to quantify the radiation emitted by the

biological tissue in units of measurement selected from the group including wavelength, radiance, luminosity, temperature, area, volume, change in temperature, rate of change of temperature, relative temperature, energy, change in energy, rate of change of energy, and relative energy.

5 The data processing and recording device may also include a memory or storage component capable of temporarily and/or permanently storing the image signals, electronic signals, and/or frames to any of a number of such components including, for example but not for limitation, random access memory, floppy disks, CD-ROMs, conventional hard disks, analog or digital video tape, and any other type of readily available storage media that is
10 presently available for such purposes.

 In a variation of the preceding embodiment, the therapeutic treatment apparatus for photostimulation of biological tissue incorporates at least one treatment radiation source providing radiation at a predetermined wavelength selected from the range approximately between 800 and 1,100 nanometers and adapted to illuminate the biological tissue. In a
15 further variation, the data processing and recording device is capable of receiving and processing the image signal and adapted to generate an electronic signal in the form of a plurality of frames corresponding to the image signal at various time intervals. Preferably, the data processing and recording device captures and analyzes the frames to quantify the radiation emitted by the biological tissue in units of measurement selected from the group
20 described above. More preferably, the data processing and recording device is further configured to control the energy output of the at least one treatment radiation source to induce and maintain a preselected energy input to and output from the biological tissue.

 The present invention also contemplates a variation wherein the data processing and recording device is configured to measure the temperature of the biological tissue and to

control the output of the at least one treatment radiation source whereby the biological tissue is heated to and maintained at a predetermined temperature for a selected period of time.

In another variation of the instant invention, the therapeutic treatment apparatus for photostimulation of biological tissue is modified wherein the data processing and recording
5 device is further configured to block the energy emitted by the at least one treatment radiation source that is reflected by the biological tissue and subtract the reflected energy from quantified unit of measure.

The present invention is also directed to a variation wherein the data processing and recording device is further configured to control the energy output of the at least one
10 treatment radiation source to induce and maintain a preselected energy input to and output from the biological tissue sans the reflected energy.

In yet another variation of the present invention, a therapeutic treatment apparatus for photostimulation of biological tissue includes at least one treatment radiation source providing radiation at a predetermined wavelength selected from the range approximately
15 between 400 and 11,500 nanometers and adapted to illuminate the biological tissue. Also included is an infrared camera configured to detect infrared radiation emitted by the target biological tissue and adapted to produce an image signal corresponding to the detected radiation and further including a filter component adapted to block radiation having the predetermined wavelength, the filter selected from the group including optical and electronic
20 filters. This variation further incorporates a data processing and recording device that is capable of receiving and processing the image signal and adapted to generate an electronic signal in the form of a plurality of frames corresponding to the image signal. The data processing and recording device is adapted to capture and analyze the frames to quantify the radiation emitted by the biological tissue in at least one unit of measurement selected from the
25 group including wavelength, radiance, luminosity, area, volume, temperature, change in

temperature, rate of change of temperature, relative temperature, energy, change in energy, rate of change of energy, and relative energy.

In an alternative configuration, the instant invention contemplates a therapeutic treatment apparatus for photostimulation of biological tissue that incorporates at least one treatment radiation source providing radiation at a predetermined wavelength selected from the range approximately between 400 and 11,500 nanometers and adapted to illuminate the biological tissue. This configuration includes an infrared camera configured to detect infrared radiation emitted by the target biological tissue and adapted to produce an image signal corresponding to the detected radiation at windows corresponding to precise moments in time. A data processing and recording device is also incorporated that is capable of receiving and processing the image signal, and which is adapted to generate an electronic signal in the form of a plurality of frames corresponding to the image signal. The data processing and recording device in this alternative configuration is adapted to capture and analyze the frames to quantify the radiation emitted by the biological tissue in at least one unit of measurement selected from the group including wavelength, radiance, luminosity, area, volume, temperature, change in temperature, rate of change of temperature, relative temperature, energy, change in energy, rate of change of energy, and relative energy. This configuration of the data processing and recording device is further modified to control the infrared camera and the energy output of the at least one treatment radiation source to emit pulses of radiation to induce and maintain a preselected energy input to and output from the biological tissue sans the reflected energy. Lastly, the data processing and recording device is further configured to block the detection of treatment radiation reflected by the biological tissue by synchronizing the timing the emitted treatment radiation pulses with the infrared camera detection windows so that the camera captures an image of the radiation emitted by the target biological tissue at a moment between radiation pulses.

The present invention also contemplates a method for use of a therapeutic treatment apparatus for photostimulation of biological tissue that includes the steps of selecting at least one treatment radiation source that provides radiation at a predetermined wavelength selected from the range approximately between 400 and 11,500 nanometers and adapted to illuminate the biological tissue. Also included is the step of selecting an infrared camera that is configured to detect infrared radiation emitted by the target biological tissue, the camera being adapted to produce image signals corresponding to the detected radiation. A data processing and recording device is selected that is capable of receiving and processing the image signals and adapted to generate an electronic signal in the form of a plurality of frames corresponding to the image signals. The data processing and recording device captures and analyzes the frames and also quantifies the radiation emitted by the biological tissue. The radiation is quantified in at least one unit of measurement selected from the group including wavelength, radiance, luminosity, area, volume, temperature, change in temperature, rate of change of temperature, relative temperature, energy, change in energy, rate of change of energy, and relative energy.

In a variation of the preceding method, the method further includes the steps of controlling the energy output of the at least one treatment radiation source to induce and maintain a preselected energy input to and output from the biological tissue; blocking the energy emitted by the at least one treatment radiation source that is reflected by the biological tissue and subtracting the reflected energy from quantified unit of measure; and controlling the energy output of the at least one treatment radiation source to induce and maintain a preselected energy input to and output from the biological tissue sans the reflected energy.

Brief Description of the Drawing

Without limiting the scope of the present invention as claimed below and referring now to the drawings, wherein like reference numerals and numerals with primes across the several views refer to identical, corresponding, or equivalent features and parts:

5 Figure 1 is a schematic representation of the various elements of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The therapeutic treatment apparatus of the present invention is generally configured for photostimulation of biological tissue. The apparatus includes at least one treatment
10 radiation source adapted to radiate electromagnetic energy at a predetermined wavelength selected from the range approximately between 400 and 11,500 nanometers. The apparatus further incorporates an infrared camera configured to precisely and continuously detect infrared radiation. The camera is adapted to produce image signals corresponding to the detected radiation. A data processing and recording device is also included that is capable of
15 receiving and processing the image signals. The data processing and recording device is further adapted to generate an electronic signal in the form of a plurality of digital frames that correspond to the image signals. The data processing and recording device is also configured to capture and analyze the frames and to quantify the radiation emitted by the biological tissue. The radiation is quantified in units of measurement selected from the group including
20 wavelength, radiance, luminosity, temperature, area, volume, change in temperature, rate of change of temperature, relative temperature, energy, change in energy, rate of change of energy, and relative energy. The data processing and recording device is also configured to detect and/or block the energy emitted from the at least one treatment radiation source that is reflected by the target biological tissue. The therapeutic treatment apparatus is also
25 configured to quantify the energy emitted by the biological tissue by blocking or subtracting

the reflected energy from the quantified result. A method for using the device in its multiple configurations, variations, modifications, and alternatives is also disclosed.

Referring now to FIG. 1, the present invention relates to an apparatus **10**, and a method for using it, that is directed to the photostimulation of biological tissue **20** such as, for example without limitation, cutaneous and subcutaneous biological tissues **30, 40**. Many types of electromagnetic radiation sources, guides, projectors, detectors, and controllers are available that are suitable for purposes of the present invention. Many such devices that include such components are disclosed in co-owned U.S. patent application serial no. 09/281,443, filed on March 29, 1999, now U.S. Pat. No. _____, and in U.S. Pat. Nos. 4,573,465; 4,966,144; 5,002,051; 5,049,147; 5,112,328; 5,139,494; 5,150,704; 5,445,146; 5,527,350; 5,540,676; 5,755,752; and 5,951,596, each of which are hereby incorporated by reference in their entirety.

The apparatus of the instant includes a therapeutic treatment apparatus for photostimulation of biological tissue that includes at least one treatment radiation source **50** that is configured to emit radiation at a predetermined wavelength selected from the range of approximately between 400 and 11,500 nanometers.

The treatment radiation source **50** may be one of a plurality of sources **50, 60, 70** each configured to emit radiation at one or more wavelengths including, for purposes of illustration but not limitation, the above described range. In configurations where more than one treatment radiation source is used, then the sources **50, 60, 70** are preferably coupled to an optical coupler **80**. The coupler **80** is further coupled to a radiation guide **90** such as a fiber optic guide adapted to communicate the radiation of the treatment source or sources.

Preferably, the at least one treatment radiation source **50** is selected from the group including semiconductor laser diodes, super-luminous diodes, light emitting devices, and solid-state laser diodes ("SSD"). More preferably, the at least one treatment radiation source

50 is configured to emit radiation having a wavelength of approximately between 800 and 1,100 nanometers. Even more preferably, the at least one treatment radiation source **50** is a neodymium-yttrium-aluminum-garnet (“Nd:YAG”) laser tuned to emit radiation having a wavelength of approximately 1,064 nanometers.

5 The fiber optic guide **90** may be further connected to a radiation focusing device such as a radiation emitting probe or wand **100** that can be manipulated by a user for purposes of irradiating the target biological tissue **20**. Each of the treatment radiation sources **50**, **60**, **70** may alternatively be coupled to additional, independent wands or probes via additional, separate fiber optic cables (not shown).

10 For configurations of the present that employ treatment radiation that is invisible to the unaided human eye, an additional radiation source configured to emit radiation in the visible spectrum, such as for example, source **70**, may be coupled to the previous treatment radiation sources **50**, **60** to operate as an aiming radiation source. Alternatively, the aiming radiation source **70** may be coupled to each of the radiation sources **50**, **60** that are

15 independently coupled to separate wands or probes similar to probe **100**. In other variations, additional aiming radiation sources (not shown) may be used to emit radiation at various visible wavelengths of light so that multiple aiming radiation wavelengths may be employed and coupled to selected treatment radiation sources. Alternatively, the radiation emitted by aiming source **70** may be split and coupled to various probes. For example, visible blue light
20 may indicate treatment radiation of a first wavelength, while visible red light emitted by a separate source may be used to indicate a different treatment radiation wavelength, and other colors may be used to indicate other types of treatment radiation. Alternatively, multiple different wavelengths of aiming radiation may be used to indicate modes of operation. For example, power settings below a certain predetermined threshold may be identified by visible
25 red light, while higher power settings may be indicated using visible blue light.

The present invention also incorporates a video-type infrared camera **110** that is preferably configured to detect infrared radiation having a wavelength approximately between 700 and 20,000 nanometers. The camera **110** is further preferably adapted to produce image signals corresponding to the detected radiation. A data processing and recording device **115** is also included in the present invention, which is coupled by signal line **120** to the camera **110** and which is capable of receiving and processing the image signals and adapted to generate an electronic signal in the form of a plurality of digitally encoded frames corresponding to the image signals. The data processing and recording device **115** preferably captures and analyzes the frames. In analyzing the frames, the data processing and recording device **115** is configured to quantify the radiation emitted by the biological tissue **20** in units of measurement selected from the group including wavelength, radiance, luminosity, temperature, area, volume, change in temperature, rate of change of temperature, relative temperature, energy, change in energy, rate of change of energy, and relative energy.

The data processing and recording device **115** may also include a memory or storage component (not shown but known to those with skill in the art) capable of temporarily and/or permanently storing the image signals, electronic signals, and/or frames to any of a number of such components including, for example but not for limitation, random access memory, floppy disks, CD-ROMs, conventional hard disks, analog or digital video tape, and any other type of readily available storage media **130** that is presently available for such purposes.

In a variation of the preceding embodiment, the therapeutic treatment apparatus **10** for photostimulation of biological tissue incorporates at least one treatment radiation source **50** providing radiation at a predetermined wavelength selected from the range approximately between 800 and 1,100 nanometers and adapted to illuminate the biological tissue **20**. In a further variation, the data processing and recording device **115** is configured for receiving and processing the image signal and adapted to generate an electronic signal in the form of a

plurality of frames corresponding to the image signal at various time intervals. Preferably, the data processing and recording device **115** captures and analyzes the frames to quantify the radiation emitted by the biological tissue **20** in units of measurement selected from the group described above. More preferably, the data processing and recording device **115** is further
5 configured to control the energy output **140** of the at least one treatment radiation source **50** to induce and maintain a preselected energy input to and output from the biological tissue **20**.

The present invention also contemplates a variation wherein the data processing and recording device **115** is configured to measure the temperature of the biological tissue **20** and to control the output of the at least one treatment radiation source **50** whereby the biological
10 tissue **20** is heated to and maintained at a predetermined temperature for a selected period of time.

In another variation of the instant invention, the therapeutic treatment apparatus **10** for photostimulation of biological tissue **20** is modified wherein the data processing and recording device **115** is further configured to block the energy **140** emitted by the at least one
15 treatment radiation source **50** that is reflected by the biological tissue **20** and subtract the reflected energy **150** from quantified unit of measure.

The present invention is also directed to a variation wherein the data processing and recording device **115** is further configured to control the energy output of the at least one treatment radiation source **50** to induce and maintain a preselected energy input to and output
20 from the biological tissue **20** sans the reflected energy **150**. This is accomplished either by configuring the device **115** or by coupling the device **115** with an independent controller **160** configured to communicate with and control the at least one treatment radiation source **50** as well as any additional sources **60**, **70**. If desired, a visible light video camera **170** may also be

incorporated into the apparatus of the present invention for purposes of monitoring and / or recording operation of the instant invention.

In yet another variation of the present invention, a therapeutic treatment apparatus **10** for photostimulation of biological tissue **20** includes at least one treatment radiation source **50** providing radiation at a predetermined wavelength selected from the range approximately between 400 and 11,500 nanometers and adapted to illuminate the biological tissue **20**. Also included is an infrared camera **110** configured to detect infrared radiation emitted by the target biological tissue **20** and adapted to produce an image signal corresponding to the detected radiation and further including a filter component (not shown) adapted to block radiation having the predetermined wavelength, the filter selected from the group including optical and electronic filters. This variation further incorporates a data processing and recording device that is capable of receiving and processing the image signal and adapted to generate an electronic signal in the form of a plurality of frames corresponding to the image signal. The data processing and recording device **115** is adapted to capture and analyze the frames to quantify the radiation emitted by the biological tissue **20** in at least one unit of measurement selected from the group including wavelength, radiance, luminosity, area, volume, temperature, change in temperature, rate of change of temperature, relative temperature, energy, change in energy, rate of change of energy, and relative energy.

In an alternative configuration, the instant invention contemplates a therapeutic treatment apparatus **10** for photostimulation of biological tissue that incorporates at least one treatment radiation source **50** providing radiation at a predetermined wavelength selected from the range approximately between 400 and 11,500 nanometers and adapted to illuminate the biological tissue **20**. This configuration includes an infrared camera **110** configured to detect infrared radiation **150** emitted by the target biological tissue **20** and adapted to produce an image signal corresponding to the detected radiation **150** at windows corresponding to

precise moments in time. A data processing and recording device **115** is also incorporated that is capable of receiving and processing the image signal, and which is adapted to generate an electronic signal in the form of a plurality of frames corresponding to the image signal.

The data processing and recording device **115** in this alternative configuration is adapted to capture and analyze the frames to quantify the radiation emitted by the biological tissue **20** in at least one unit of measurement selected from the group including wavelength, radiance, luminosity, area, volume, temperature, change in temperature, rate of change of temperature, relative temperature, energy, change in energy, rate of change of energy, and relative energy.

This configuration of the data processing and recording device **115** is further modified to

control the infrared camera **110** and the energy output of the at least one treatment radiation source **50** to emit pulses of radiation **140** to induce and maintain a preselected energy input to and output from the biological tissue **20** sans the reflected energy **150**. Lastly, the data processing and recording device **115** is further configured to block the detection of treatment radiation **150** reflected by the biological tissue **20** by synchronizing the timing the emitted treatment radiation pulses with the infrared camera detection windows so that the camera **110** captures an image of the radiation being emitted by target biological tissue **20** at a moment between radiation pulses.

The present invention also contemplates a method for use of a therapeutic treatment apparatus for photostimulation of biological tissue **20** that includes the steps of selecting at least one treatment radiation source **50** that provides radiation at a predetermined wavelength selected from the range approximately between 400 and 11,500 nanometers and adapted to illuminate the biological tissue. Also included is the step of selecting an infrared camera **110** that is configured to detect infrared radiation emitted by the target biological tissue **20**, the camera **110** being adapted to produce image signals corresponding to the detected radiation.

A data processing and recording device **115** is selected that is capable of receiving and processing the image signals and adapted to generate an electronic signal in the form of a plurality of frames corresponding to the image signals. The data processing and recording device **115** captures and analyzes the frames and also quantifies the radiation **150** emitted by the biological tissue **20**. The radiation is quantified in at least one unit of measurement selected from the group including wavelength, radiance, luminosity, area, volume, temperature, change in temperature, rate of change of temperature, relative temperature, energy, change in energy, rate of change of energy, and relative energy.

In a variation of the preceding method, the method further includes the steps of controlling the energy output of the at least one treatment radiation source **50** to induce and maintain a preselected energy input to and output from the biological tissue **20**; blocking the energy emitted by the at least one treatment radiation source **50** that is reflected by the biological tissue **20** and subtracting the reflected energy from quantified unit of measure; and controlling the energy output of the at least one treatment radiation source **50** to induce and maintain a preselected energy input to and output from the biological tissue **50** sans the reflected energy **150**.

The present invention establishes a significant advance over the previously known devices and methods and the advance is achieved with improved accuracy, simplicity, and without any significant increase complexity of technology.

Thermography is a preferred technique for detecting soft tissue anomalies occurring in various types of biological tissues. Anomalous tissues often experience an altered blood flow circulation. One of the most prominent indicators of anomalies such as inflammation and other injuries is heat, which is due to increased blood circulation. A medical thermogram is a methodology, which allows the detection of such biological soft tissue anomalies by measuring the surface temperature of the target biological tissue.

Thermography is a noninvasive diagnostic application that uses infrared radiation detection technology to quantify the surface temperatures of the target biological tissue and subjacent structures. By converting thermal emissions into a multi-colored "map" wherein various colors correspond to certain wavelengths of emitted radiation, temperature differences as small as approximately between 0.05 and 0.08 degrees Celsius can be detected. In addition to detecting increased heat radiation of target biological tissues, the thermographic techniques of the present invention also contemplate detection of areas where blood circulation is decreased. This can occur where anomalies exist such as nerve damage, a blood clot, and development of subjacent scar tissue. In these anomalous biological tissues regions, the thermographic image may depict cooler than expected temperatures, such as may be expected in tissues that suffer from the initial stages of atrophy or other form of deterioration. It will be understood by those with skill in the art that pathologies of the cutaneous and subcutaneous structures including, for example, tendons, ligaments may be identifiable through identification of the "hot spots" and "cool spots" that while invisible to the unaided human eye, are prominently revealed by thermography. Such anomalous biological tissues can thus be detected as far in advance as two weeks before the onset of clinically detectable signs of injury and/or anomaly.

Various types of thermographic cameras, signal processing, and analysis equipment are known in the prior art that includes U.S. Pat. Nos. 5,959,444; 5,467,126; 5,637,871; and 5,386,117. Vendors known to have cameras and related equipment that are suitable for purposes of use with the present invention include Sierra Pacific Innovations #2, www.x20.org, 1034 Emerald Bay Rd., Dept. 437, South Lake Tahoe, California; Rod Hall International, Inc., www.rodhall.com, 1360 Kleppe Lane, Sparks, Nevada; Microlytics, Inc., www.endeavorship.com, P.O. Box 2022, Stillwater, Oklahoma; Raytheon Systems Company, www.raytheoninfrared.com, 6380 Hollister Avenue, Goleta, California; Infrared Components

Corporation, www.infraredcomponents.com, 2306 Bleecker Street, Utica, New York; and Indigo Systems Corporation, www.indigosystems.com/cameras.html, 5385 Hollister Ave #103, Santa Barbara, California.

Numerous modifications and variations of the preferred embodiments disclosed herein

5 will be apparent to those skilled in the art. For example, although specific embodiments have been described in detail, those with skill in the art can understand that the preceding embodiments and variations can be modified with various types of treatment radiation sources and thermographic camera and data processing devices for desired compatibility with the wide variety of modalities presently in use for photostimulation of biological tissues.

10 Accordingly, even though only few variations of the present invention are described herein, it is to be understood that the practice of these additional modifications and variations and the equivalents thereof, are within the spirit and scope of the invention as defined in the following claims.

WE CLAIM:

1. A therapeutic treatment apparatus for photostimulation of biological tissue, comprising:

at least one treatment radiation source emitting a predetermined wavelength selected from the range approximately between 400 and 11,500 nanometers and adapted to irradiate the biological tissue;

an infrared camera configured to detect infrared radiation emitted by the target biological tissue and adapted to produce image signals corresponding to the detected radiation;

a data processing and recording device configured for receiving and processing the image signals and adapted to generate an electronic signal in the form of a plurality of frames corresponding to the image signals; and

wherein the data processing and recording device captures and analyzes the frames to quantify the radiation emitted by the biological tissue in at least one unit of measurement selected from the group including wavelength, radiance, luminosity, temperature, change in temperature, rate of change of temperature, relative temperature, energy, change in energy, rate of change of energy, and relative energy.

2. The therapeutic treatment apparatus of Claim 1, wherein the data processing and recording device records only temporarily.

3. The therapeutic treatment apparatus of Claim 1, wherein the data processing and recording device is further configured to quantify the radiation emitted by the biological tissue in units of measurement selected from the group including area and volume.

4. The therapeutic treatment apparatus of Claim 1, wherein the at least one treatment radiation source is selected from the group including semiconductor laser diodes, super-luminous diodes, light emitting devices, and solid-state laser diodes.

5. The therapeutic treatment apparatus of Claim 1, wherein the at least one treatment radiation source is a Nd:YAG SSD laser tuned to emit radiation having a wavelength of approximately 1,064 nanometers.

6. The therapeutic treatment apparatus of Claim 1, wherein the at least one treatment radiation source is configured to emit radiation having a wavelength of approximately between 800 and 1,100 nanometers.

7. A therapeutic treatment apparatus for photostimulation of biological tissue, comprising:

at least one treatment radiation source providing radiation at a predetermined wavelength selected from the range approximately between 800 and 1,100 nanometers and adapted to illuminate the biological tissue;

an infrared camera configured to detect infrared radiation emitted by the target biological tissue and adapted to produce an image signal corresponding to the detected radiation;

a data processing and recording device configured for receiving and processing the image signal and adapted to generate an electronic signal in the form of a plurality of frames corresponding to the image signal at various time intervals;

wherein the data processing and recording device captures and analyzes the frames to quantify the radiation emitted by the biological tissue in at least one unit of measurement

selected from the group including wavelength, radiance, luminosity, temperature, area, volume, change in temperature, rate of change of temperature, relative temperature, energy, change in energy, rate of change of energy, and relative energy; and

wherein the data processing and recording device is further configured to control the energy output of the at least one treatment radiation source to induce and maintain a preselected energy input to and output from the biological tissue.

8. The therapeutic treatment apparatus of Claim 7, wherein the data processing and recording device is configured to measure the temperature of the biological tissue and to control the output of the at least one treatment radiation source whereby the biological tissue is heated to and maintained at a predetermined temperature for a selected period of time.

9. The therapeutic treatment apparatus of Claim 7, wherein the at least one treatment radiation source is selected from the group including semiconductor laser diodes, super-luminous diodes, light emitting devices, and solid-state laser diodes.

10. The therapeutic treatment apparatus of Claim 7, wherein the at least one treatment radiation source is a Nd:YAG SSD laser tuned to emit radiation having a wavelength of approximately 1,064 nanometers.

20

11. The therapeutic treatment apparatus of Claim 7, further comprising:
at least one additional treatment radiation source configured to emit radiation having a wavelength of approximately between 800 and 1,100 nanometers.

12. A therapeutic treatment apparatus for photostimulation of biological tissue, comprising:

at least one treatment radiation source providing radiation at a predetermined wavelength selected from the range approximately between 800 and 1,100 nanometers and adapted to illuminate the biological tissue;

an infrared camera configured to detect infrared radiation emitted by the target biological tissue and adapted to produce an image signal corresponding to the detected radiation;

a data processing and recording device configured for receiving and processing the image signal and adapted to generate an electronic signal in the form of a plurality of frames corresponding to the image signal at various time intervals;

wherein the data processing and recording device captures and analyzes the frames to quantify the radiation emitted by the biological tissue in at least one unit of measurement selected from the group including wavelength, radiance, luminosity, area, volume, temperature, change in temperature, rate of change of temperature, relative temperature, energy, change in energy, rate of change of energy, and relative energy; and

wherein the data processing and recording device is further configured to block the energy emitted by the at least one treatment radiation source that is reflected by the biological tissue and subtract the reflected energy from quantified unit of measure.

13. The therapeutic treatment apparatus of Claim 12, wherein the at least one treatment radiation source is selected from the group including semiconductor laser diodes, super-luminous diodes, light emitting devices, and solid-state laser diodes.

14. The therapeutic treatment apparatus of Claim 12, wherein the at least one treatment radiation source is a Nd:YAG SSD laser tuned to emit radiation having a wavelength of approximately 1,064 nanometers.

5 15. The therapeutic treatment apparatus of Claim 12, further comprising:
at least one additional treatment radiation source configured to emit radiation having a wavelength of approximately between 800 and 1,100 nanometers.

10 16. A therapeutic treatment apparatus for photostimulation of biological tissue, comprising:

at least one treatment radiation source providing radiation at a predetermined wavelength selected from the range approximately between 800 and 1,100 nanometers and adapted to illuminate the biological tissue;

15 an infrared camera configured to detect infrared radiation emitted by the target biological tissue and adapted to produce an image signal corresponding to the detected radiation;

a data processing and recording device configured for receiving and processing the image signal and adapted to generate an electronic signal in the form of a plurality of frames
20 corresponding to the image signal at various time intervals;

wherein the data processing and recording device captures and analyzes the frames to quantify the radiation emitted by the biological tissue in at least one unit of measurement selected from the group including wavelength, radiance, luminosity, area, volume, temperature, change in temperature, rate of change of temperature, relative temperature,
25 energy, change in energy, rate of change of energy, and relative energy;

wherein the data processing and recording device is further configured to block the energy emitted by the at least one treatment radiation source that is reflected by the biological tissue and subtract the reflected energy from quantified unit of measure; and

5 wherein the data processing and recording device is further configured to control the energy output of the at least one treatment radiation source to induce and maintain a preselected energy input to and output from the biological tissue sans the reflected energy.

17. The therapeutic treatment apparatus of Claim 16, wherein the at least one treatment radiation source is selected from the group including semiconductor laser diodes,
10 super-luminous diodes, light emitting devices, and solid-state laser diodes.

18. The therapeutic treatment apparatus of Claim 6, wherein the at least one treatment radiation source is a Nd:YAG laser tuned to emit radiation having a wavelength of approximately 1,064 nanometers.

15

19. The therapeutic treatment apparatus of Claim 16, further comprising:
at least one additional treatment radiation source configured to emit radiation having a wavelength of approximately between 800 and 1,100 nanometers.

20 20. A therapeutic treatment apparatus for photostimulation of biological tissue, comprising:

at least one treatment radiation source providing radiation at a predetermined wavelength selected from the range approximately between 400 and 11,500 nanometers and adapted to illuminate the biological tissue;

an infrared camera configured to detect infrared radiation emitted by the target biological tissue and adapted to produce an image signal corresponding to the detected radiation and further including a filter component adapted to block radiation having the predetermined wavelength, the filter selected from the group including optical and electronic
5 filters;

a data processing and recording device configured for receiving and processing the image signal and adapted to generate an electronic signal in the form of a plurality of frames corresponding to the image signal; and

wherein the data processing and recording device captures and analyzes the frames to
10 quantify the radiation emitted by the biological tissue in at least one unit of measurement selected from the group including wavelength, radiance, luminosity, area, volume, temperature, change in temperature, rate of change of temperature, relative temperature, energy, change in energy, rate of change of energy, and relative energy.

15 21. A therapeutic treatment apparatus for photostimulation of biological tissue, comprising:

at least one treatment radiation source providing radiation at a predetermined wavelength selected from the range approximately between 400 and 11,500 nanometers and adapted to illuminate the biological tissue;

20 an infrared camera configured to detect infrared radiation emitted by the target biological tissue and adapted to produce an image signal corresponding to the detected radiation at windows corresponding to precise moments in time;

a data processing and recording device configured for receiving and processing the image signal and adapted to generate an electronic signal in the form of a plurality of frames
25 corresponding to the image signal;

wherein the data processing and recording device captures and analyzes the frames to quantify the radiation emitted by the biological tissue in at least one unit of measurement selected from the group including wavelength, radiance, luminosity, area, volume, temperature, change in temperature, rate of change of temperature, relative temperature, energy, change in energy, rate of change of energy, and relative energy;

wherein the data processing and recording device is further configured to control the infrared camera and the energy output of the at least one treatment radiation source to emit pulses of radiation to induce and maintain a preselected energy input to and output from the biological tissue sans the reflected energy; and

wherein the data processing and recording device is further configured to block the detection of treatment radiation reflected by the biological tissue by synchronizing the timing the emitted treatment radiation pulses with the infrared camera detection windows so that the camera captures an image of the target biological tissue at a moment between radiation pulses.

22. A method for using a therapeutic treatment apparatus for photostimulation of biological tissue, that includes the steps of:

selecting at least one treatment radiation source that provides radiation at a predetermined wavelength selected from the range approximately between 400 and 11,500 nanometers and adapted to illuminate the biological tissue;

selecting an infrared camera configured to detect infrared radiation emitted by the target biological tissue and adapted to produce image signals corresponding to the detected radiation;

selecting a data processing and recording device configured for receiving and processing the image signals and adapted to generate an electronic signal in the form of a plurality of frames corresponding to the image signals; and

capturing and analyzing the frames with the data processing and recording device;

5 and

quantifying the radiation emitted by the biological tissue in at least one unit of measurement selected from the group including wavelength, radiance, luminosity, area, volume, temperature, change in temperature, rate of change of temperature, relative temperature, energy, change in energy, rate of change of energy, and relative energy.

10

23. The method according to Claim 22, further comprising the step of controlling the energy output of the at least one treatment radiation source to induce and maintain a preselected energy input to and output from the biological tissue.

15

24. The method according to Claim 22, further comprising the step of blocking the energy emitted by the at least one treatment radiation source that is reflected by the biological tissue and subtracting the reflected energy from quantified unit of measure.

20

25. The method according to Claim 22, further comprising the step of controlling the energy output of the at least one treatment radiation source to induce and maintain a preselected energy input to and output from the biological tissue sans the reflected energy.

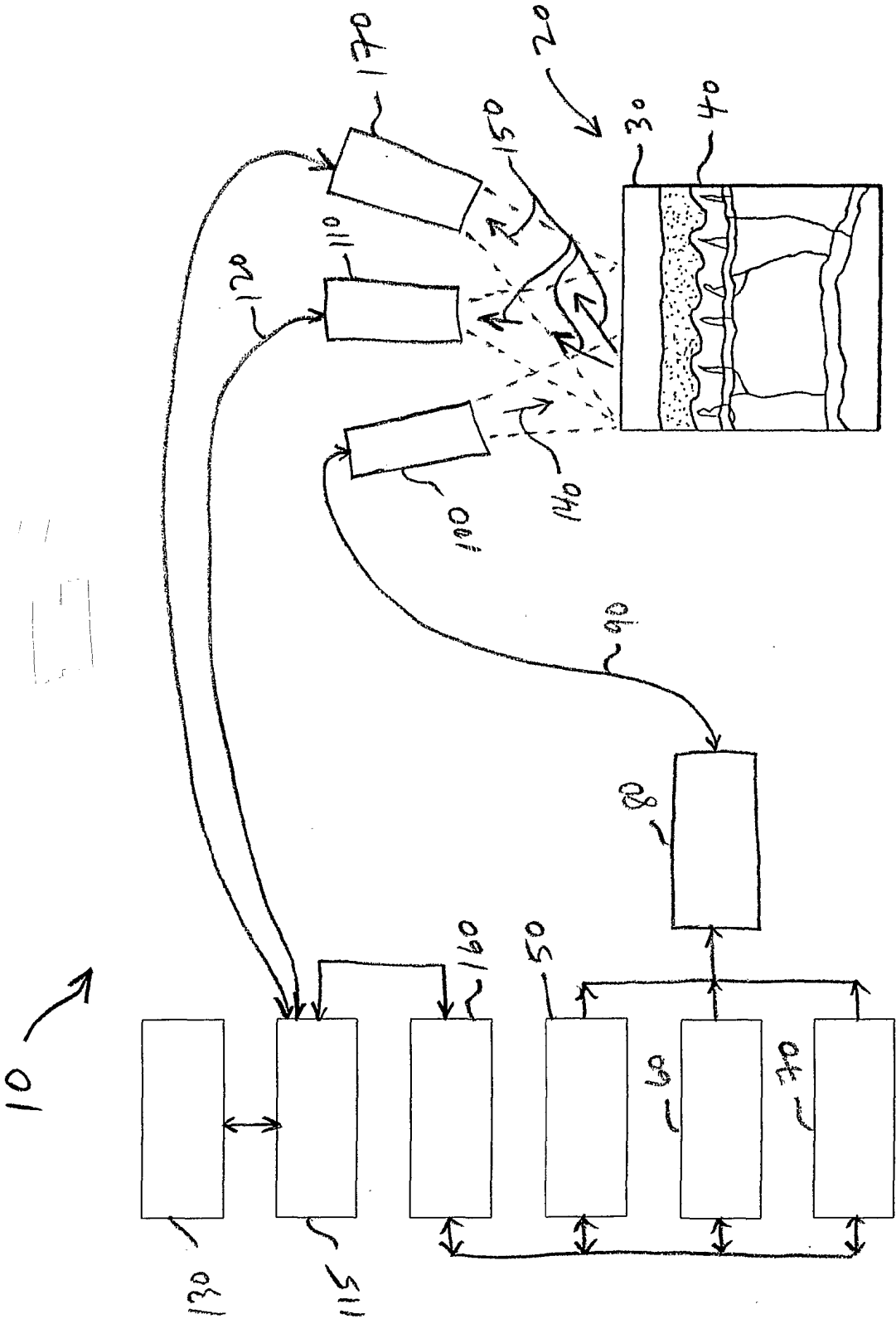


FIG. 1